JAINA ASTRONOMY

DR. S.S. LISHK

The thesis approved by Punjabi University, Patiala for the Degree of Ph.D. in the faculty of science in the year 1978 and awarded outstanding merit by Dr. H. Hirosi (Japan) & DR. W. Petri (West Germany).

Foreward by :

DR. A.I. VOLODARSKY
U.S.S.R. Academy of Sciences, MOSCOW

Introduction by :

DR. A.K. BAG
Indian National Science, Academy,
New Delhi

A Note by :

PROF. L.C. JAIN
Research Associate (INSA)
Rani Durgavati University, Jabalpur

First Published August 1987
Rupees Two hundred.

Published by :

Mrs. KUSUM JAIN
VIDYA SAGARA PUBLICATIONS
(Oriental and Scientific Research Publication Centre)
B-5/263, Yumuna Vihar,
DELHI-110053
INDIA

Printed at : A.R. Printers, Delhi-110053.

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FOREWARD

Today in the whole of the world there is an increasing interest in the study of all the aspects of the history of science in India. The reason lies in the great achievements and improvements attained by the Indian people in each of the fields during last decades.

The historians of science in USSR have the privilege to get to know all new publications of Indian colleagues. We know very well the works of all the outstanding and distinguished Indian historians of mathematics and astronomy.

The present work deals with the mathematical analysis of Indian astronomy in the post-Vedāṅga pre-Siddhāntic period, i.e., circa first millenium B.C. to first centuries A.D. About this pre-Āryabhata-I period we have very few scientific evidences. It is great Dr. S.S. Lishk's merit who revealed to us these little known pages of the history of mathematics and astronomy.

In previous decades some historians of science believed that Siddhāntic mathematics and astronomy owe their origin to Mesopotamian and Greek science. Now we have the factual evidence to show that the main parts of Siddhāntic mathematics and astronomy are traceable to the Harappan culture and there are unremitting tradition and persistent connection between these two epochs.

This book by Dr. S.S. Lishk is the outcome of his detailed and long investigations into the astronomical texts wrapped in the religious scriptures of the pre-Christian era. He is the author of more than 50 articles devoted to different aspects of the history of Indian mathematics an astronomy. I hope that he will continue his investigations and will make further notable contributions to these fields of knowledge.

DR. Alexander VOLODARSKY
Institute of the history of Science and Technology
USSR Academy of Science, MOSCOW, USSR.

INTRODUCTION

The Jaina literature is vast. Their canonical texts, 45 or 50 in number, besides subsidiary texts, contain a wide range of information dealing with religion, philosophy, society, mathematics, astronomy and other scientific subjects. The basic texts are classified as *Aṅgas, Upāṅgas, Prakirṇakas, Chedasūtras* and *Mūlāsūtras*. The tradition holds that the canon was taught by Mahāvīra Jīna and handed down for generations from 3rd or 4th century B.C. It was resuscitated from time to time through conferences. The councils of Pataliputra and Vallabhi (6th century A.D.) are quite well-known. The original texts are said to have been lost and are known to have been recasted by the Svetāmbara Sect of the Jainas in Ardha-Māgadhi Prākṛt from existing fragments and oral traditions.

The Aṅgas are twelve in number and these are the *Ācārāṅga, Sūtrakṛtāṅga, Sthānāṅga, Samavāyāṅga Bhagavati* or *Vyākhyāpajñapati, Jñātṛdharmakathā, Upāsakadaśā, Antakṛtadaśa, Anuttarnaupapātikadaśa. Praśnvyākaraṇa, Vipākasūtra* and *Dṛṣṭivāda.* They mostly deal with doctrinal matter, rituals, legends etc. Of these, the *Sthānaṅgā* and *Bhagavatīsūtra* contain information on mathematics and astronomy.

The *Upāṅgas* are also twelve in number but are not directly related to the *Aṅgas*, These are *Aupapātika, Rajapraśniya, Jīvājīvābhigama, Prajñapanā, Sūryaprajñapti, Jambūdvīpaprajñapti, Candraprajñapti, Nirṇayāvalī, Kalpāvatamsikā, Puspikā, Puspacūlikā* and *Vṛṣṇidaśāḥ*. The texts *Jīvājīvābhigama* and *Jambūdvīpaprajñapti*, give good account of Jaina cosmography, and the *Sūryaprajñapti, Candraprajñapti* and *Jambūdvīpaprajñapti* supply good information of Jaina astronomy.

The Prakīrṇakas are miscellaneous texts and are ten in number. They deal with varieties of materials relating to the canon and serve like Pariśiṣthas. The *Anuoyogadvārasūtra* and the *Nandisūtras* sometimes included in the *Prakirṇakas*, also carry information on mathematics and astronomy. The *Chedasūtras* are

nine in number and deal with life, code of conduct for monks and nuns, monastic jurisprudence etc. The *Mūlasūtras* are four of which the *Uttaradhyāna* only contains information on mathematics and astronomy.

Other post-canonical Jaina literature covers a wide range of texts dealing with astronomical information including astronomical instruments. These are the *Tattvārthādhigamasūtra* of *Umāsvāti* (A.D. 185-219), *Trilokaprajñapati* of Yativṛṣabha (c. A.D. 473), *Jyotiṣakaraṇḍaka* (based on *Sūryaprajñapti*), *Karaṇānuyoga* or *Gaṇitānuyoga*, *Yantrarāja* of Mahendra Suri (A.D, 1348), the court astronomer of Sultan Feroz Shah Tughlaq, *Yantrarājaracanā* by Malayendu Suri, a commentary on the Yantrarâja, *Jyotisrāsa* of Thakker Pehru (14th century), *Dinaśuddhi* of Ratnaśekhara Sūri (15th century), *Maṇḍalaprakaraṇa* of Vinayakusala, *Ustaralaya-yantra* of Meghalaya (c. 1500 A D.), *Karaṇarāja* by Muni Sundara (c. 1600 A.D.), *Jyotiḥprakāra* by Jnānabhusana and many other works A number of *Pancāṅgas* dealing with daily calendar are known to have been composed by later Jaina scholars.

The Jaina astronomy was considered an important branch of study and an essential equipment for a Jaina priest for computing the correct time for religious performance. The *Sūryaprajñapti*, *Jambūdvīpaprajñapti* and *Candrapajñapti* the fifth, sixth, and the seventh *Upaṅgas* give full depiction of the astronomical concepts and practices of the Jainas. The first and third texts are entirely on astronomy while the second deals astronomy only in the last section. The Jain canonical literature are classified later into four collections entitled *Dharmokathānuyoga*, *Caraṇānuyoga*, *Gaṇitānuyoga* (or *Karaṇānuyoga*) and *Dravyānuyoga*. Matters relating to astronomy, mathematics, geography and allied subjects have been collected in the *Gaṇitānuyoga*. In 1865, Waber (*Indische Studien*, 10, pp.254-316) understood the importance of the *Sūrya-prajñpti* and pointed out that it embodied the same astronomical elements as characterized by *Vedāṅga Jyautiṣa*. The study was taken in detail by Thibaut who published a big article in the Journal of the Asiatic Society of Bengal (49, pp.107-127, 181-21) in 1880. The principal source of these works was Malayagiri's

commentary *Sūrya prajñaptivṛtti*. The *Sūryaprajñapti* deals with various astronomical views of the Jainas on orbits of the sun during the year, the rising and setting of the sun, the velocity of the course of the Sun through each of its 184 cubits, the altitude of the sun and Moon, the measures of the shadow lengths, various seasons of the year, the connection of the Moon with the lunar mansions (*nakṣatras*), the waxing and waning of the Moon, the velocity of the five kinds of heavenly bodies Sun, Moon, Planets, Nakṣatras, Tārās, the qualities of the moon-light, the number of suns in the Jambūdvīpa s. The knowledge of astronomy was considered necessary to find the time and place for the religious ceremony *Sankhāna* (arithmetic) and *Joisa* (astronomy) are mentioned in the *Bhagavatisūtra* (2.1) and the *Uttaradhyana sūtra* (2⁵.7.36) as one among fourteen branches of learning. The experts of *Joisa* were required to forecast also of coming events.

The *Sūryapajñapti* has revealed five year luni-solar cycle, similar to the teachings of *Yājuṣa* and Ārca Jyautisa starting from the beginning of summer solstice. The data yielded 29. 516120 days for its sidereal revolutions. It also considered 19 years period. The results are better than *Vedāṅga Jyautiṣa* but less accourate than the latter Siddhāntas. Unlike *Vedāṅga Jyautiṣa*, it used a stellar frame of 28 nakṣatras of unequal space. It also showed the peculiarity of two sets of Sun, Moon and Nakṣatra series, which was criticized severely by Brahmagupta.

Dr. Lishk's study indeed gives us excellent survey of status of astronomical knowledge available from Jaina cannons before the Siddhāntic period often handicapped by reference from texts of uncertain date. This work initiates the great task of bridging a big gap between Vedāṅga Jyotisa and Siddhantic astronomy. The role of Jaina school of Astronomy in development of Siddhāntic astronomy is also highlighted in his pioneering work relating to the dark period in the history of ancient Indian Astronomy. The Jaina literature is vast and is considered important sources for early information on astronomy beside others. Most of our knowledge is based on only the *Sūryaprajnapti* and Candraprajñapti. The Jaina works like *Bhadrabāhu Samhitā* are the unlimited sources of more investigations and have ample data regarding kinematical

studies of planets like Mercury and Mars etc. Even *Bhagavati sūtra*, *Jambūdvipaprajnapti* have not been seriously and critically studied. Nor the authentic critically edited texts dealing with astronomical information are easily available. The availability of authentic critically edited texts with English translation and modern studies is the need of the hour for actual assessment. This will help scholars in appreciating the stagewise developments of the knowledge and establish its role in the development of Āryabhaṭa and other Siddhāntic schools of astronomy in India.

A. K. BAG
Executive Secretary
Indian National Science Academy
New Delhi.

A NOTE

BY PROF. L.C. JAIN, Jabalpur (M.P.)

"In the temple of Science are many mansions, and various indeed are they that dwell therein and the motives that have led them thither".

—A. Einstein

The origination and evaluation of a scientific spirit in India is now clearer from the recently translated Prakrit texts, as also from those which had remained unexposed to the scientific world so far. These texts of the Jaina School belong to the Karanānuyoga (study of operations) group, which forms a basis for the texts of Dravyānuyoga (study of fluents) group. The text of the Karaṇānuyoga group involve study of mathematical concepts of measures which lie embedded in the Jaina texts of the Karaṇānuyoga group, and thus become a system of tools for an interdisciplinary study between the cosmographical and cosmological universes motivated by the Jaina School.

Out of the four groups, Prathamānuyoga (preliminary study), Karaṇānuyoga, Caraṇanuyoga (character study), and Dravyānuyoga, the above two groups form a deeper study into the secrets of nature. The texts, for example, are classified by some of the authors as under :

Karaṇānuyogu group	*Dravyānuyoga group*
Tiloyapaṇṇatti	Kasāyapāhuḍa
Trilokasāra	Saṭkhaṇḍāgama
Jambūdivapaṇṇatti	Gommaṭasāra
Saṃgaho	
Sūryaprajñapti	Labdhisāra
Candraprajñapti	Samayasāra
Loka vibhāga	Pañcastikāya

These compendium texte, demanding basically the existence of omniscience, go a long way, depicting a postulational basis, principle-theoretic in character, set-theoretic in approach and system-theoretic in detail. For example, a geometric model of its universe, subdivided into three parts, locates all types of fluents, eternally existent, unchanged in their constitution, yet changing their states every instant : souls and matter behaving quite apart from the rest of the fluents. That is why the necessity for a systematic study of these two types of texts arises for motivating research through mathematics.

From these texts, it becomes evident that the Jaina philosophy took recourse to mathematical manoeuvre and got evolved in a unique school of study. Its religious activities were based on such a scientifically naive exploration for a safe and blissful world through a theory of Karma (action). The Karma theory showed the way to attainment of omniscience with all that was blissful, eternal and omnipotent, for an accomplishable soul. Thus cosmology was a means for accomplishable ends.

As already pointed out, the Jaina texts deal with system-theoretic details, and the theory of Karma itself is a system theory exposed through various subsystems out of which astronomical subsystem forms a subject of study.

The astronomical subsystem lies close in study in the geographical subsystem on one hand and to the cosmographical system on the other. The three subsystems had to be fit in the "measure" subsystem adopted in the Jaina school. The secret lies in the following verse of the Tiloyapaṇṇatti, Vol, I, ch.1.

पल्ल समुद्दे उवमं अंगुलयं सूइ पदर घणणामं ।
जग सेढि लोय पदरो य लोओ अट्ठप्पमाणाणि ॥93॥
ववहारुद्धारद्धा तियपल्ला पढयम्मि संखाओ ।
विदिए दीवसमुद्दा तदिए मिज्जेदि कम्मठिदी ॥94॥
तिवियप्पमंगुलं तं उच्छेह पमाण अप्प अंगुलयं ।
परिभासाणिप्पण्णं होदि हु उच्छेहसूचि अंगुलयं ॥107॥
तं चिय पंच सयाइं अवसप्पिणि पढम भरह चक्किस्स ।
अंगुल एक्कं चेव य तं तु पमाणंगुलं णाम ॥108॥

The first two verses describe three types of Palya (time measure instant-set), the Vyavahāra Palya measures number, the Uddhāra Palya measures islands-oceans etc., and the Addhā Palya measures the life-time of Karmas. Similarly the lattee two verses describe three types of Aṅgula, the Utsedhāṅgula measures heights, altitudes of bios and their residence, Pramāṇāṅgula measures the dimension of inlands, oceans, rivers, regions etc., whereas the Atmāṅgula measures small articles with the help of self Aṅgula (finger) of people of their own-regions and own-times.

Thus it requires a deep study how these units of measure have been applied and results obtained regarding geographical, astronomical and cosmographical objects. Before application one has also to be particular about the origin and axes of reference for each of their setting before measurements are made.

For location of geographical objects, a grid system is introduced in discoidal maps of the Jaina school, where earth has been regarded flat, as it seems, in so far as the Jambū island and Lavaṇa ocean is concerned, and similar concepts as well as perfect symmetry in setting of objects in succession of islands and oceans, alternate set with double the diameters of the preceding ones, in forms of rings after the Jambū island. Attention is drawn when one wishes to find the location of various rivers, cities, mountains, in the very Jambū island, noted for its own high structure of the Meru mountain, abstracted in frustrums of cones through mathematically perfect symmetry. This structure is set in the middle universe which lies inbetween the lower and upper universe or inbetween the hellish and heavenly regions.

Through this grid system, descriptions have been made in Jaina works through measuses in *Yojnas* which could be compared with Chinese '*Li*" which meant principle of organization or intrinsic pattern. The measure of Yojana is also of three kinds depending upon the unit of Aṅgula used. Rising to the heights of the Meru, one could observe horizons after horizons, extended and more extended beyond vision. Yet the Jambū island itself was to be fit in the actual world in which people of the period lived and recognized various objects really existent, in scale of measure best

known to them, through shadow reckoning, geometry of the circle and the straight line, framing a cartographical record of scientific or quantitative value. These records seem to have been lost, in course of time, and we get records of religious or symbolic geography alone which could have survived due to religious culture. The religious or symbolic geography, as found in religious texts cannot be used to explain the cartography of the day, which ought to have been far finer in detail.

Now we pass on to the astronomical setting in the very cosmographical picture. The cosmos or the whole universe or the non-empty space has been given in terms of a Rāju, the Cosmic unit of distance in Jaina school, meaning a Rope, a very old concept prevalent in Egypt. But here this is related with the total number of heavenly bodies through its logarithm to the base two. (Cf. Tilyapaṇṇatti, Vol.2, Ch.VII, VV. 2 et seq) The following verse gives its value through a set-theoretic approach :

अद्धारपल्ल छेदो तस्सासंखेय भाग मेत्ते य ।
पल्ल घणंगुल वग्गिद संवग्गिदयम्हि सूइ जग सेढी ॥131॥
तं वग्गे पदरंगुल पदराइ घणे घणंगुलं लोगो ।
जगसेढीए सत्तमभागो रज्जू पभासंते ॥132॥

(Cf. Tiloyapaṇṇatti, Vol. 2, Ch. 1.,).

In this finite non-empty space, an astro-universe is set up in the following verse :

रज्जुकदी गुणिदव्वं एक्क सय दसुत्तरेहिं जोयणए ।
तस्सि अगम्म देसं सोधिय सेसम्मि जोदिसिया ॥5॥

(Cf. Tiloyapaṇṇatti, Vol.2, Ch.7)

The five types of the astral bodies described are the moon, the sun, planets, constellations and scattered stars. The moon heads the rest of its family. The set of total astral bodies is (Jagaśreṇi) 2 ÷ 65536.

Now the position of the orbits and the movements of the astral bodies in the Jambū island and Lavaṇa ocean are described in terms of Yojana and Gagana-Khaṇḍa (skyzones), per muhūrta

(forty eight minutes). The origin of the Gagana-Khaṇḍas is the Abhijit (set of stars) constellation, one of the twenty eight, with smallest stretch, the occultation point of the beginning of five-year Yuga system. The origin of the Yojana measurements of altitudes of the heavenly bodies apprears to be *Citrā*. The Citrā appears to be the first deep layer of the earth in the beginning of the lower-universe with several minerals and with thickness stated to be one thousand Yojanas. In the very central portion of Trasanālī, and upper portion of the Citrā, there is an extremely spherical human-universe with a diameter of forty-five lacs of Yojanas. In the very central portion of the human-universe, is the first island, named Jambū, which is similarly circular, having a diameter of one lac Yojana. (Cf. TP. Vol.1, Ch.4,VV.6,11) As the Yojana is related with the three types of Aṅgulas, its theoretic measures would be correlated with the following equations : (Cf. TP, Vol.1, VV.1 et) seq.)

[Jagaśrenī=(Aṅgula cubed) $^{(\text{log Palya/Asaṃkhyāta})}$] and

[Sūcyāṅgula=(Palya) $^{(\text{log}_2\text{Palya})}$]

Where Jagaśreṇi and Sucyāṅgula are point-sets as existential sets and Palya is instant-set as a construction-set.

Meru, for the measures of distances from its axis, may be regarded as celestial axis. Directions, Gagana Khandas, Yojanas, and relative motion of heavely bodies with respect to each other per muhūrta relate to a coordinate geometry of the Kinematics in the Jaina school of astronomy. With this material, apart from methods of shadow-reckoning, colours at eslipses, relative velocity data of heavely bodies through Gagana-khaṇḍas and Yojanas and science of sciatherics of the Jaina school, Sajjan Singh Lishk has been able to fathom deep into the secrets of the ancient Jaina school of astronomy with partial success. They have tried to distinguish between the geographical units of Yojana and astronomical units of Yojana by delving deep into various texts of the Jain school and tried to correlate them through great efforts, yet a lot of work remains to be done for the research scholars.

One peculiar aspect of study of the Jaina school of mathematics is its approach through projection of reality through abstract mathematical or geometrical or algebraical details specially in astro-

nomy. Their two suns and two moons theory alongwith pairs of their families, along a duplicate path gives the idea of the real and counter heavenly bodies quoted in other civilizations, meant for calucations of eclipses or some such phenomena. The kinematical details could be very well used to find every information from the resultant five-year Yuga calendar, although not so fine as the modern values. The calendar of the Vedāṅga Jyotisa worked for about one thousand years, and when the solstices and seasons began to change at the calculated time, the Jaina calendar came into force with a mathematical base regarding the geometro-kinematics of the heavenly bodies. This was only a part of a much extensive study in the Jaina school whose aim was emancipation through omniscience, and the phenomena of the observables led to astronomical and perhaps astrological studies. Yet the phenomena of the non-observables, the Karma systematism, was far deeper in mathematical display, and astrology seems to have been set on one hand with the astronomy and on the other hand as it seems with the mathematicol theory of Karma, detailed symbolically in the Gommaṭasāra and the Labdhisāra.

It was a unique attempt of the Jaina school to be able to divide the sky into zones, Gaganakhandas or celestial zones : a zodiac for the pair of the families of heavely bodies in Jambū island, with a stretch of 54900 Gaganakhaṇḍas for the real side. A five year Yuga cycle contains 54900 muhūrtas and the Ṛtu Rāhu, moving 1° per day, describes this stretch of 54900 Gagana khaṇḍas in 360 days. This easily suggests how the idea of 360° got evolved in ancient world. This set, thus constituted 109800 celestial zones for the real and counter bodies. But, working with half the diagram is sufficient to give all calendrical details. Similar symmetrical structures were supposed to constitute the whole astral universe, at different Meru of the other islands, a limit being set for movement of the astral bodies, beyond which the astral bodies are stated to be at rest. The lunar zodiac of the Jaina school appears to be similar to that of China.

A simple question arises regarding the motion of the sun and the moon. The diurnal and annual motions are combined in the description given by authors of Karaṇānuyoga texts, They are spiro-elliptic orbits, but the authors describe them through circles or rings, with discontinuous stretches per day, or jumps every day.

What is the implication of such a description ? The motions of the sun and the moon are continuous in space and time, hence there can be no jumps. As such it appears that the attempt to simulate the real unified picture of the motion of astral bodies was made in India, for the first time, and later on the ptolemic picture began to prevail in form of epicycles which could give the instantaneous picture in place of the diurnal picture of the motion of the astral bodies.

Now one may find how Lishk tried to approach the problem of Yojana. He has found that a Yojana is to be approximated on the basis of the speculation that

1 Pramāṇa Yojana = 500 Atma Yojanas
= 1000 Utsedha Yojanas
= 8 Tiloyapaṇṇatti Yojanas

It appears, that on this basis, Lishk stipulated that Citrā be considered as celestial equator from which the heights of the astral bodies had been reckoned in angular measure proposed by him.

For example, the height of the sun is given as 800 Yojanas above the Citrā. Lishk calculates this as $\frac{800 \times 6.7}{69.9} = 76°$, The difference in height of the moon ie 80 Yojanas or $7°.6$, for which the modern value of the orbital inclination to the eliptic is $5°8'40''$. But this does not hold so close for remaining planets, as it holds for the moon and the planet mercury.

While at a symposium, Lishk in personal discussions told me about the problem whether 366 days per year were in vogue in the Jaina school, or it was just a usage for a five year Yuga cycle. Did the school know as to where the coincidence with the star, having precessional movement, of the sun took place in its orbit ? As related by him, there is a connecting link given in the work, "Gaṇitānuyoga".

"The land in which the sun is in Yoga on the last 62nd Amāvasyā, from the Amāvasyā station, on reaching 94th part of 124 parts of the orbit, the sun is in Yoga on the first Amāvasyā." Similarly, again in the five-year Yuga, the sun is in Yoga on the

first Purnimā. "The land in which the sun is in Yoga on the last 62nd Purṇimā, from that Purṇimā station, on reaching the 94th part of 124 parts of the orbit, the sun is in Yoga on the first Purnimā." (Cf. Gaṇitānuyoga, (1970), pp. 303, 305.

From the above data one easily finds that after 365th day of the year, the hours passed for such positions of the sun are $\frac{30 \times 24}{124}$ $=5.81$ hours, or 5 hours, 48 minutes and 5.98 seconds. Similarly, very accurate periods for the moon were described by the Jaina school, through Kinematics. The data of such a calculation, if found, will be important for the history of astronomy.

Lishk has found that various types of occultations of the moon were studied minutely by the Jaina school. The eclipse theory of five colours investigated by him relates that a unified cycle compounding 42 eclipse months cycle of lunar eclipses and 48 eclipes years cycle of solar eclipses could be determined from these colours. The Parva Rāhu and his celestial car of five colours have a significance for the nodes of the moon in Jaina school of astronomy.

The Jaina school developed principle theoretic means, whereas the Greeks developed construction theoretic means in ancient times. The unified theory of spiro-elliptic orbital motion of the Jain school was principle-thoretic, whereas the epicycles theory of the Greeks was construction theoretic. The approaches were different but the ends were the same.

Lishk has also concentrated on the problems in astronomy through shadow reckoning prevalent in ancient Jaina school. Season's determination depends on this technique. Similarly he has tried to establish that the longest and shortest day-calculation was feasible, under certain circumstances, at Ujjain, in the ratio of 3:2.

It is due to the undying credit of Lishk that the Jaina school of astronomy could be traced to its deeper insights and implications, confirming the view that India developed its astronomy independently, both as a principle theretic achievement in the post-Vedānga and pre-Siddhāntic period, and as a construction theoretic achievement in the Siddhāntic period. Thus India seems to have influenced

other civilizations more than it was influenced in return, in the field of astronomy, by resorting to both types of approaches.

The thesis of Lishk is a consequence of the hard task he pursued for revealing to the world his keen intellect as well as deep interest in the mathematical part of the Jaina literature which is generally avoided in the Indological or Jainological studies. His work will serve as a precept for the future scholars, for his thesis has crossed the frontiers of the previous knowledge of the Jaina astronomy among the world historians, through the usual hurdles of an Indian research worker. There is no doubt that his research work will be appreciated more and more when studied deeply, and when extended to university courses.

PREFACE

The history of astronomy owes its origin to a remote antiquity. In the cradle of human civilization, history reveals that man's place in nature has always been relevant to religion[1]. The curiosity for regulating the mode of periodic religious performance must have catered to the need for the observation of celestial phenomena. To cite an example, it was customary among the Chinese emperors who sacrificed to heaven at Winter solstice, to earth at Summer solstice and to the imperial ancestors during the first month of Spring[2]. The study of any celestial phenomena was aimed at purely assisting mode of their religious life For instance, we may smile at what difference does it make to religion whether the sun revolves round the earth or the earth around the sun, but the innocent calculations of Copernicus had stirred a great disturbance in the religious outlook for a full century after 1543 A.D.[1] were Likewise in China since the Han dynasty, calendarical reforms considered indispensable in order to keep the political and cosmic orders in tune[3]. Thus scientific problems in general, and mathematical as well as astronomical problems in particular show their full meanings, as Carrucio[4] remarks, when they are considered in their own historical backgrounds respectively. The historical study of astronomy presents a dynamic view which can measure the future by

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1. Hocking, W.E. (1944), Science And The Idea of God, p. 85. See also Pannekoek, A. (1930), Astrology And Its Influence Upon The Development of Astronomy, Journal of The Royal Astronomical Society of Canada, Vol. XXIV, No. 4, pp. 159-17 .
2. Brodrick, A. H., (1940), The Sacrifices of The Son of Heaven, The Asiatic Review. Vol XXXVI, No. 125, pp. 123.
3. Yabuuti, K., (1968) Comparative Aspects of The Introduction of Western Astronomy Into China And Japan, Sixteenth To Nineteenth Centuries, The Chung Chi Journal, Vol. 7, No. 2. PP. 151-154.
4. Carrussio, E. Mathematics And Logic in History And Contemporary Thought, Eng. Tr. by Isabel Quingly, (1964), p. 9,

the past. Such antiquitic studies render a great tribute to the memories of primitive thinkers who devoted their lives to the grotesque study of celestial phenomena for the formulation of description of the real world around.

Most of the western scholars hold the opinion that Hindus borrowed much of their sciences from Greece[1]. Such outlook renders a hindrance in proper evaluation of the Hindu contribution in its true perspective. The facts and figures from earlier texts of India have as yet remained unexposed to the western window due to several reasons. Primarily, as Dange opines that history was used by the English rulers of India to demnralise the rising freedom movement; to build a psychosis in the leadership of the people that compared world history, its age and its achievements, Indian history leads to conclude that this country and its people were historically destined to be always conquered and ruled by foreign invaders[2]. Secondly, dared by fire arms and dazzled by the enterprise and the material advancement of the foreign intruders, Indians began to look down upon native scholarship and achievements[3]. Thirdly, we had no Papyrus Prisse to prove our age, no pyramids of Giza, nor mummies of Akhnaton and Tutankhamen, no towns dug up like Ur and Babylon except the Vedas, the Purāṇas and the like to speak for us[4],

However, much of the ancient Veda, as Plunket opines, still remains a Cypher and it can be properly revealed only with the help of modern sciences[5]. It may, of course, be noted that the Vedāṅga Jyotiṣa (Vedic astronomy) has already been commented upon by several scholars like Somākara (first edited by Weber and again edited by S. Dvivedi), Thibaut, Bārhaspatya, R. Shamasastry,

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1. Allen, R.H., (1936) Star Names And Their Meanings, Second reprint, introduction.
2. Dange, S. A., (1972) India, fifth ed., p.2.
3. Saraswathi, T.A. (1969) Development of Mathematical Ideas In India, IJHS, Vol. 24, Nos. 1&2, pp. 59-78.
4. Dange op. cit.
5. Roy, B.B., The Universe, p. 41.

B.R. Kulkarni, G. Prasad, A.K. Chakravarti and Pingree etc. Despite some controversial view points, everything is clear about Siddhantic taxts also, as some theses like those of M.L. Sharma, D.A. Somayaji, and R Billiard etc. are scholarly works of profundity in this field. But still there lies a big gap between the Vedāṅga Jyotiṣa period and that of Siddhântic astronomy. This gap, the so called dark period, has hitherto remained a forgotten chapter in the history of ancient Indian astronomy. Scholars like S B Dixit, B.G. Tilak and D. Pingree seem to have also overlooked the need for investigation into this period. Here it is proposed to analyse mathematically the astronomical data extant in Jaina canonical literature. Regarding the chronology of Jaina works, the astronomical method[1] has been depended upon. Since there had been an oral tradition of handing down the knowledge from preceptor to the pupils[2], evidently the ancient texts contain much that is far older than the period of compilation of their present recensions. Therefore chronological determination cannot be asceratained through qualitative approach based upon linguistic studies. The astronomical method is objective in nature and it takes into account the uniqueness of astronomical events. However, qualitative approach has also rendered, admittedly no less important a role in unearthing some additions, subtractions and other later interpolation in the original scriptures. A few semantic changes can also no longer be overlooked than they are taken into consideration for eulogising the real sense of the word in its ancient usage. Occasionally modern mathematics has to be depended upon for the proper understanding of some Jaina concepts which had been formulated in their primitive forms, albeit traceable inadequately, much before they were originated on the foundation of modern symbolism.

It may be remarked here that a rational approach has been aimed at deriving conclusions with a supreme regard for textual evidence vide use of primary sources as far as possible. A pre-

1. Daftary, K.L., (1942), The Astronomical Method And Its Application To The Chronology of Ancient India.
2. Sikdar, J.C., (1964), Studies In Bhagavatī Sutra, p. 32.

conceived chronology has been disregarded unlike Kuglar who was one of the Panbabylonistic School and created a fantastic picture by ascribing everything to Babylon[1]. Besides, it is also worth-mentioning that there are two types of approaches, viz.,

i. Critical analysis of a standard text,

ii. Collection of relevant data on a certain topic from various texts in chronological order and then analysing the same to have a perspective view.

We have adopted the second one. Verily it may be emphasized that we must remodel our mental framework alike to that of the ancient Jaina scholiasts in order to delve deep into the secrets of their attainments in the field of astronomy. Sometimes apparently quite a vague expression viewed through its own historical background also leads to certain inferences of excellence. There is hardly any exorbitance of opinion that much of the astronomical information is garbed in the fabrics of Jaina peculiar system of thought. The astronomical significance of the data is revealed from the mathematical nature of the sequence of results abtained thereform. Due emphasis has been laid upon the contents of mathematical interest. However, peculiar theories like that of two suns, two moons etc. have been investigated into their secrets, not because that Jainas had or not actually believed in them, but because they formed part and parcel of their tentative astronomical model of cosmos which was alpiu designed to corroborate their mode of description of the real world around us.

Here it may be mentioned that there are certain aspects which are similar to both the Vedāṅga Jyotiṣa and the Jaina astronomy, e.g five-year cycle ; four periodic measures viz. sāvana (civil), saura (solar), lunar and nākṣatric (sidereal) ; use of zigzag functions and variation of daylight etc. But Jaina astronomical achievement exhibits a stage far advanced than Vedāṅga Jyotisa period There seem several unique developments in Jaina astronomical period, e.g., notions of declination, celestial latitude and obliquity of ecliptic ; method of measurement of celestial distances projected over

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1. Neugebauer, Otto, (1952), The Exact Sciences In Antiquity, p. 132.

the surface of the earth ; systems of units of time, length and arc division ; the use of shadow lengths for the determination of season and the time of day elapsed at any instant. Besides, it is worthy of note that Jaina astronomical system exhibits certain peculiar characteristics of Siddhāntic astronomy, such as planetary motion, measurement of celestial angular distances, use of zigzag and linear step functions, shifting of first point of zodiacal circumference from winter solstice to Vernal equinox, latitudinal motion, notion of declination, notion of obliquity of ecliptic, graduation of zodiacal circumference, heliacal motion, lunar occultations and sub-divisions of time etc.[1] On the other hand, Jaina astronomical system does not seem show to explicit use of Siddhāntic rāṣis (ecliptic signs), explict reference to week days, epicyclic theory and geometrical methods used in Siddhāntic astronomy. Still it is our conjecture that Jainas might have strived for arriving at better methods for computing longitudinal and latitudinal positions of astral bodies as is evidenced by their trends towards kinematical studies of the sun, the moon and venus, etc. However comparison of Sūrya Siddhānta radii of epicycles with those of Ptolemy shows origination of Sūrya Siddhānta constants. Here it is worthy of note that the above mentioned astronomical notions extant in Siddhāntic astronomy are traditionally ascribed to the Greek influence upon ancient Indian astronomy. It is however to be emphasized that the pre-Siddhāntic Jaina School of astronomy has been chiefly characterised by its own symbolism, technical terminology and other peculiar notions ; and it is still in want of exposition of all compendimum of Jaina astronomical knowledge before the extent of link between Siddhāntic astronomy and western astronomy can properly be discerned. It is, of course, easily discernible that Jaina astronomical system does not show any distinct indication of influence of western systems of ancient astronomy. Besides, Jaina astronomical system incorpoates no fringe of any non-explicit helio-centric hypothesis as is

1. Lishk, S. S. and Sharma, S. D., (1977), Role of Pre-Āryabhata-I Jaina School of Astronomy In The Development of Siddhāntic Astronomy, IJHS, Vol. 12, No, 2 pp. 106-113.

dimly said to have been postulated by Aristarchus of Samos[1] ih c 280 B.C. Consequently Pingree's view[2] about Mesopotamian origin of ancient Indian mathematical astronomy become questionable. In fact, the idea that Siddhāntic astronomy had, in toto, been borrowed from the Greeks[3] was de facto the product of a spontaneous jump from Vedānga Jyotiṣa to Siddhāntic astronomy. Certain peculiarities[4] between Vedānge Jyotiṣa and Paitāmaha Siddhānta such as five year cycle from the conjuction of sun and moon at the first point of Dhaniṣṭa (β Delphini) and ratio of greatest and shortest lengths of daylight, etc., have been misleading as regards the use of Vedic astronomical system upto the epoch of Paitāmaha Siddhānta (A.D. 80) after which the Vedic astronomical system underwent a radical change with the emergence of the Siddhāntic astronomy. It may also be noted that, the Paitāmaha Siddhānta of Varāhamihira's Pañcasiddhāntikā (five systems) represents Indian astronomy as not yet influenced by Greeks and in this respect it belongs to the same category as the Jyotisa Vedānga, the Sūrya Prajñapati and other similar works. This thesis has clarified several links in unearthing the systematic emergence of ancient Indian astronomy right from the Jyotiṣa Vedānga to the Siddāntic astronomy. Some scholars like L.C. Jain, R.C. Gupta and S.D. Sharma have also produced a few articles in this field. The author's contribution in this dissertation consists in presenting abinitio an exhaustive account of the Jaina school of astronomy such that it opens a new vista of knowledge for further research in this field. This work initiates the task of bridging the gap between the Vedanga Jyotiṣa and the Siddhāntic astronomy. Still more revelations are due to corroborate the role of Jaina school of astronomy in the development of Aryabhaṭa I and other Siddhāntic Schools of astronomy.

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1. Kuppanashastri, T.S. (1974), The Main Characteristics of Hindu Astronomy In The Period Corresponding To Pre-Copernican European Astronomy, IJHS, Vol 9, No. 1, pp. 31-34.
2. Pingree, D., (1973), Mesopotamian Origin of Ancient Indian Mathematical Astronomy. JHA. Vol. 4, pp. 1-12.
3. Ibid,
4. Cf. Pañca Siddhāntikā, pp. 548-549.

Some other Jaina non-canonical works like, the Tiloyasāra, and Bhadrabāhu Samhitā etc. also need thorough investigation. A critical study of the contemporary Budhistic School of astronomy[1] is of utmost importance. The present day tradition of celebration of Vega star function among the Japanese highlights the scope of any such possibilities of transmission of some Jaina astronomical notion towards the far east alongwith the spread of Buddhism. Somes contacts as pointed out by Puri established between Jaina saints and foreigners, some of whom might be presumed to have been attracted to Jainology in the early centuries of Christian era, also need a thorough investigation. This dissertation has paved the way for the execution of such types of research programmes which would lead on completion to brighten the dark period in the history of ancient Indian astronomy.

ACKNOWLEDGEMENT

The author refrains from his vain attempt to employ the meagre medium of expression in words for acknowledging his deep sense of gratitude towards Dr. S. D. Sharma for suggesting the problem, unstinted help, able guidance and persistent encouragement in the completion of this work, and towards Shanti Muni, a Jaina monk, for his kind blessings and introducing a book the author had for the first time come across in this field. Thanks are due to Dr. B. S. Sood, Dr. Sukhmandar Singh, Jagjiwan Singh Kanjla, Karam Singh Rasia, Dr. S. Bhiksu, P. V. Sharma, Chandan Muni Barnala, and several colleagues and friends for their kind help in one way or the other.

The author pays his best tribute to the memory of his grandfather, late Sardar Sucha Singh, whose utmost desire for his higher education has always kept him alive towards his research activities.

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1. Petri, W., (1968), Tibetan Astronomy, Reprinted from "Vistas In Astronomy" (Ed. Arthur Beer), Vol. 9, pp. 159-164.
2. Puri, B.N., (1968), Jainism In Mathurā In The Early Centuries of the Christian Era, Mahavira Jaina Vidyalya Golden Jubilee Volume, p. 157.

The author is extremely grateful to his parents, sisters, Mrs. Patwant Kaur (wife) and Yogipal Singh and Lochanmeet Singh (sons) who cheerfully bore all the interruptions during this period.

Thanks are due to numerous scholars for their learned works which have been useful in preparation of this work. The author is indebted to Professor Dr. A. I. Volodarsky for writing his kind foreword and Dr. A. K. Bag for writing his learned introduction. The Author in Sincerly thankful to Professor L. C. Jain for his learned note The author is highly obliged to Mrs. KUSUM Jain, the publisher, who has been keenly instrumental for bringing out this publication in antiquitic studies in Indology.

—SAJJAN SINGH LISHK

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ERRATA

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82	5	Primordial	Rimordial
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143	20	Observer's	Observerer's
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CHAPTER I

Sources of Jaina Astronomy

1.1. JAINA CANONICAL LITERATURE :

Jaina canon of sacred literature comprises of a vast treasure of knowledge. Jaina canonical works are encyclopaedic in contents including various aspects of Jaina philosophy and history such as political, social and economic conditions, education, different modes of religious life ; cosmology, cosmography, geography, mathematics, astronomy and evolution of Jaina philosophical thought etc. The oldest part of the Jaina canon is traditionally represented by the fourteen 'pūrvas' (the former scriptures) and the twelfth aṅga (literally, the limb) Dṛṣṭivāda, which have now become extinct. According to tradition, the present āgamas or sacred books of the Jaina canon have been extracted from a single small section.[1] Besides, the opinion that lord Mahāvīra first composed 'Pūrvagata Śruta' (the old scriptural verbal knowledge) suggests that the fourteen pūrvas (the former scriptures) and the twelfth aṅga (limb) Dṛṣṭivāda were one and the same.[50] Belike the common people could not follow pūrvas (the former scriptures), thus the twelfth aṅga (limb) Dṛṣṭivāda might have been composed for the benefit of less intelligent persons.

The existing āgamas (sacred books of the Jaina canonical literature) have been classified as follows :

1. *Aṅgas* :

The twelve aṅgas (limbs) constitute a class of literature popularly known as Gaṇipiṭaka or Dvādaśāṅgī literally meaning the twelve limbs (of the Jaina canon). They form nucleus of the entire Jaina canon.[57] They are named in their chronological order as follows :

(1) Ācārāṅga, (2) Sūtrakṛtāṅga,
(3) Sthānāṅga (4) Samavāyāṅga
(5) Vyākhyā Prajñapti (6) Jñatr-dharmakathāṅga,
(7) Upāsakadaśāṅga (8) Antakṛddaśāṅga

(9) Anuttara-aupapatikadaśāṅga (10) Praśna-vyākaraṇa
(11) Vipāka Sūtra (12) Dṛṣṭivāda

2. *Upāṅgas* :

There are twelve upaṅgas (sub-limbs), *viz.*

(1) Aupapatika (2) Rajapraśnīya
(3) Jīvajīvabhigama (4) Prajñapana,
(5) Sūrya Prajñapti (6) Jambūdvīpa Prajñapti
(7) Candra Prajñapti (8) Nirnayāvali
(9) Kalpāvatamśikā (10) Puṣpika
(11) Puṣpaculika (12) Vṛṣnidaśah

3. *Prakīrṇakas* :

The word 'Prakīrṇaka' means 'miscellany'. There are ten Prakīrṇakas, meaning dispersed texts, *viz.*

(1) Causaraṇa (2) Aura-paccakkhāṇam
(3) Bhattapariṇṇā (4) Santhāraga
(5) Taṇḍulaveyāliya (6) Candāvijjhaya
(7) Devindatthava (8) Ganivijjā
(9) Mahāpaccakkhāna (10) Vīratthava.

4. *Cheda Sūtras* :

The word 'cheda' means 'cut'. Probably such treatises prescribed 'cuts' in seniority of monks on their violating monastic discipline but their existing recension also deals with several topics pertaining to monastic jurisprudence.[58]

There are nine cheda sūtras, meaning books of decision or statutes, *viz.*

(1) Nisīha (2) Mahānisīha
(2) Vavahāra (4) Ayāradasāo
(5) Bṛhatkalpa Sūtra (6) Daśaśrutaskandha

5. *Mūla Sūtras* :

Mūla Sūtras (literally original texts) seem to imply a notion of foundations of the Jaina religious instruction.[59] Some scholars are of the view that they are the original texts containing original words of Lord Mahavira,[58] twenty-fourth tīrthaṅkara (ford-maker) of the Jaina sect. There are four mūla sūtras (original texts), *viz.*

(1) Uttaradhyayana Sūtra (2) Avaśyaka Sūtra
(2) Daśavaikālika (4) Piṇḍaniryukti

6. *Culikā Sūtras* :

The word 'culika' means 'appendix'. Thus culika sūtras may

be taken as appendices to the entire Jaina canon.[20] There are two such individual texts, *viz.*

(1) Nandī Sūtra (2) Anuyogadāra Sūtra

As such, the number of Jaina canonical texts is stated to be forty-five or fifty ; this number may go upto eighty-four plus thirty-four Nigamas or Upaniṣads if some subsidiary elements are also taken into account. But the principal texts are aṅgas, Upaṅgas, prakīrṇakas, cheda sūtras and mūla sūtras ;[3] as well culika sūtras (the two individual texts) are prominent.

Be it noted that according to Digambara tradition, the only surviving pieces of Dvadśaṅgi (twelve limbs) are preserved in Dṛṣṭivāda (twelfth limb) and a bit of the fifth aṅga Vyākhyā Prajñapti. They constitute works like Karama-Pāhuḍā and Kasaya-Pāhuḍā popularly known as Dhavala and Jaya Dhavala Siddhāntas after the names of their respective commentaries. On the other hand, Śvetāmbras believe that only the first elevent aṅgas (limbs) are preserved though in a mutilated form, while the twelfth aṅga Dṛṣṭivada is lost. Thus the two traditions mutually complement each other to a certain extent.[14]

Besides astronomical texts are scatterred in Jaina canonical works encyclopaedic in nature describing various aspects of Jaina philosophy. The same text is repeated at sevearal places. However, works like Sūrya Prajñapti, Jambūdvīpa Prajñapti and Candra Prajñapti are the principle sources of Jaina astronomical texts extant these days

Many parallel references are found in different works of Jaina canon Besides, the general character of Jaina canonical works as regards their identical familiar similies, metaphors, analogies, language and phraseology also bears upon their close relationship. But a detailed account of literary criticism is out of scope of this work. However it is worthy of note that the present recension of Bhagavatī Sūtra, the fifth aṅga (limb), contains 1,84,000 padas (verses) whereas Samavāyāṅga Sūtra reeords only 84,000 padas of the fifth aṅga. It is therefore probable that Bhagavatī Sūtra had not attained even half of its present recension before Samavāyāṅga Sūtra was compiled This suggests that a few additions, subtractions and interpolations seem to have mutilated the original texts of the canon.

It was Ārya Rakṣita[3] or Samanta Bhadra[70] who later classified all the topics dealt with in Jaina canonical works into four anuyogas (parts) viz

1. Caraṇānuyoga
2. Dharmakathānuyoga (Prathamānuyoga)[66]
3. Gaṇitānuyoga (Karaṇānuyoga)[66]
4. Dravyānuyoga

Gaṇitānuyoga comprises of geographical and astronomical texts of Jaina canonical literature. But here we are restricted to the analytical study of astronomical texts alone

(a) *Language of the Jaina Canonical Works*

Jain canonical works have been written in dialogue form between the lord and his disciples—Gautama or Jambū. These works had been merely preserved in the memories of Jaina monks before they were finally redacted at the council of valabhī. Consequently language of the present recension of Jaina canon must have been intertangled with some regional dialects. It is therefore not less than a herculean task to comment upon the language of the original texts of Jaina conon. However, as per an ancient tradition among the tīrthaṅkaras (frod-makers),[38] Lord Mahāvīra, the twenty fourth and the last tīrthaṅkara (ford-maker), is said to have preached his doctrines of religion and philosophy in Arddha-Māgadhī' (Half-Māgadhi: meaning the language being spoken in half the state of Magadha or the language equipped with half the characteristics of the language of Magadha)[67] lauguage so that the common man could have followed his holy message.[4] Sudharman Swāmin is also said to have composed all the sūtra granthas (Jaina canonical works) in Arddha-Māgadhī. Winternitz however opines that there is also a difference of language of prose and that of verses.[63] Jacobi[5] opines that language of Jaina canon is Jaina Mahārāṣṭrī but his views have been refuted by Pischel.[6] According to Woolner,[7] both Arddha-Māgadhī and Mahārāṣṭrī have deen used in different portions of the canon. Manmohan Ghosh[8] ascribes some later form of Saurasenī to language of the canon. J.C. Sikdar[9] calls it a later Arddha-Māgadhī. In the light of foregoing discussion, it is contemplable that language of Jaina canonical works is some or the other form of Arddha-Māgadhī. However it is remarkable to note that language of Jaina canon is Ardha-Māgadhī and that of Buddhist canon is pālī inspite of the fact that both the canons

were the product of the same place and time. This problem is however out of purview of this work and is hoped of the linguists to unravel this mystery in an independent manner.[44]

(b) *Authorships and date*

According to Jaina tradition. Gautama Indrabhūti and Sudharman Swāmin became the heads of the Nirgrantha order (sect without books) in succession after the demise of lord Mahāvīra, the twenty-fourth and the last tīrthaṅkara (ford-maker) of the Jain sect Sudharman Swāmin had transmitted the sacred instructions of the Āgamas (sacred books of the Jains canon) to Jambū Swāmin The sacred instructions are addressed to Jambū in some Āgamas and to Gautama in some others as we find from the present recension of the Jaina canonical literature. A council of monks in Pāṭlīputra had met early in the third century B.C. and collected the Jaina canonical literature comprising of eleven aṅgas (limbs) and fourteen pūrvas (old scriptures)[10] and thus established a fragmentary canon called 'siddhānta' (system) from which the present canon of the Śvetāmbras may be taken to have been derived.[42] Although the process of writing had come into vogue about fifth or sixth century B C. in India,[41] yet Jaina canonical texts were preserved in the memories of Jaina monks till their present recensions were redacted in the council of Valabhī under the presidency of Devarddhi Gaṇin in about 454 A D. or 467 A D. as the date is incorporated in Kalpa Sūtra.[11] This council of Valabhī is also said to have met during the reign of Dhruvasena[12] I, from ca A. D 519 to 526. According to another tradition,[10] Jaina canon is said to have been redacted in the council of Mathurā (467 A D.) under the presidency of Skandilācārya. Besides, S. K. Jain[44] gives the chronological order of various Jaina councils as :

(i) the first in 362 B.C. under the guidance of Bhadrabāhu and Āryasthūlbhadra in Pāṭlīputra,

(ii) the second in 150 B. C at the time of Kharwel, the Sovereign king of Kalinga, at Kumārī Parvat (Virgin mount) near Bhubhneshwar,

(iii) the third in 66 A.D. under the guidence of Arhat Bali in Mahimā Nagarī of the South.

(iv) the fourth in 300 A.D. under the guidance of Skandilā-

cārya and Nāgârjunācārya in Mathurā and Valabhī respectively, and

(v) the fifth in 466 A.D. under the guidance of Devaraddhi Gaṇin in Valabhī.

Besides it is said that the council of Valabhī had edited a redaction of Jaina canonical texts in nearly the same form as existed at that time.[13] However, some alterations and corrections due to subjectivity and scholarship of the redactors cannot be ruled out.

Besides, according to Digambara tradition, the only surviving pieces of the original Dvādaśāṅgī (twelve limbs) were verbally transmitted from preceptor to disciple till the present recension of the fragmentary works was redacted soon after the demise of Lohācārya, the last of the śruta-jñānīs (learned monk who were given verbal instruction), who lived upto 683 years after the nirvāṇa (libration from corporeal existence) of lord Mahāvīra (527 B C.)[14]

So in the light of foregoing discussion. It seems plausible that the present recension of Jaina canon may in a broader sense be assigned to fifth/sixth century A D But the Jaina canon, as Pingree[12] also opines, contains much that surely belongs to a far older period than the early sixth century A.D. Sūrya *Prajñapti*, one of the principal sources of Jaina astronomy, is also believed to have been written a few years before Christian era.[15] Acording to Srinivasiengar, Sūrya Prajñapti and Jambūdvīpa Prajñapti belong to a period of about 500 B.C. and Sthānāṅga, Uttarādhyana, Bhagavatī and Anuyogadvāra to about 300 B.C[16] According to some others,[18] Bhagavati, Uttarādhyayana and Anuyogadvāra belong to about first century B.C. : Samavāyāṅga to about fourth century B C. and Prajñapana to about second century B.C. According to H.P. Bhatt,[17] Sūrya Prajñapti belongs to 400 B.C. and Candra Prajñapti to 200 B.C. According to K.S. Raghavan,[47] Sūrya Prajñapti was probably written in about 528 B.C.

It may be noted that some scholars opine that Sūrya Prajñapti and Candra Prajñapti are the name variants of one and the same text.[39,40] But there exists a manuscript of Malayagiri's Sanskrit commentary of Candra Prajñapti slightly different than that of his published commentary of Sūrya Prajñapti at Abhya Jain Library Bikaner[46] and still a different version of Candra Prajñapti is available at Atma Ram Jaina Library, Ambala City.[48]

On the other hand, N.C. Shastri considers Sūrya Prajñapati as a work contemporary of Vedāṅga Jyotiṣa and he further assigns it on the basis of linguistic approach to about 500 B.C.[19] But Thibaut[20] has calculated that there is a difference of 1246 years corresponding to a procession of 17.°3, between periods of Vedāṅga Jyotiṣa and Sūrya Prajñapti ; Thibaut has also given a caution as to the uncertainty of this deduction, but still N.C. Shastri's views are quite refutable about the contemporaneity of Sūrya Prajñapti and Vedāṅga Jyotiṣa. However by a process of counting how many times the same themes have been repeated in the various Jaina canonical texts, Jacobi and Schubring[21] concluded that the most ancient portions of the cannon were composed during third and fourth centuries B.C. However the sixth century B.C., the age in which Mahāvīra (twenty-fourth tīrthankara or ford maker of Jaina sect) was born, was a period of great intellectual stir and a ferment in the realm of thought.[37]

It may however be borne in mind that any sharp division of time cannot be demarcated in between periods of Vedāṅga Jyotiṣa and pre-Siddhāntic Jaina astronomical texts extant in Jaina āgamas Evidences are wanting in support of this view :

1. There is a legend (see Maitraiya Brāhmaṇa iii. 230 11) that Abhijit (α Lyrae) was dropped from the list of nakṣtras (lunar mansions of the Hindus) but Taittirīya Brāhmaṇa (I.5.2.3) marks it as a new comer. In Vedāṅga Jyotiṣa there is no account of Abhijit (α Lyrae) nakṣtra (asterism) whereas Jaina astronomical system is tout a fait based on the system of twenty eight nakṣtras including Abhijit (α Lyrae). This might suggest that antiquity of the Jaina astronomical system may be antedated to that of Taittirīya Brāhmaṇa.
2. Week days are not mentioned in Jaina canonical texts. Atharva Veda Jyotiṣa[22] gives an explicit reference to seven days of the week. It indicates that Jaina astronomical texts might belong to a period prior than Atharva Veda Jyotiṣa was compiled, or say, subject to some later interpolations incorporated in it.
3. The system of reckoning 'ayana' (half the annual course of the sun) in Vedāṅga Jyotiṣa is different than that in Jaina astronomy. According to Sūrya Prajñapti, dakṣiṇāyana (southern course of the sun) begins with Abhijit (α Lyrae) nakṣatra

(asterism) occurring on first day of the dark lunar half of the month of Śrāvaṇa (first lunar month of Jaina's five-year fixed calendar) whereas according to Vedāṅga Jyotiṣa, Uttarayana (northern course of the sun) begins with Dhaniṣṭhā (β Delphini) nakṣatra (asterism) occurring on the first day of the bright lunar half of the month of Māgha (seventh lunar month of Jaina five year fixed calendar). Evidently Jainas followed Pūrṇimānta (months ending with full-moon day) paddhati (system) and Amānta(months ending with new-moon day) paddhati (system) as followed in VJ period. Despite the fact that winter solstice had receded from Dhaniṣṭhā (β Delphini) to Abhijit (α Lyrae) in due time, emphasis may be laid upon the improbability of an overnight change from Amānta system to Pūrṇimānta system. Both systems must have been co-existent at least over a few centuries and Pūrṇimānta system prevalent in Jaina canonical works might have gained over the other with passage of time. Nemichand Jain[23] also advocates the view that Jaina astronomical system grew independently.

4. Still a high antiquity of the Jaina School of Astronomy is revealed from the Jaina tradition of 'tīrthaṅkaras' (ford-makers). Jaina mythology[65] takes account of a past and a future aeons of renovation of the world and each is assigned 24 tīrthaṅkaras. Mahāvīra is the last of the present round of twenty four tīrthaṅkaras (ford-makers). In this context, B N. Luniya[48] remarks in his article entitled 'Jaina Iconography' as:

> "Ṛṣabhanātha, the first tīrthaṅkara, is mentioned in the Viṣṇu and Bhāgawat purāṇas as belonging to a very remote past. The earliest Brāhmaṇical literature makes reference to a seer who defied the Vedas and opposed animal sacrifices.. The Yajur Veda mentions the names of three tīrthaṅkaras-Ṛṣabha, Ajit and Ariṣṭanemī. Jainism became a popular sect during the time of Pārśvanātha, the 23rd tīrthaṅkara, who is believed to have lived in the eighth century B.C."

This suggests that Jaina doctrine of karma (deed) may be antiquated to Yajura Veda period and undoubtedly to pre-Mahāvīrian times.[62] Here it may be emphasized that Jaina astronomy also followed the course of Jaina philosophy, for

astronomy was considered as part and parcel of philosophy and the knowledge of astronomy, as Sānticandragaṇa states in his preface to his commentary on Jambūdvīpa prajñapti, was an indispensable accomplishment on the part of a Jaina priest who was to decide the right time and place of religious ceremonies Besides, mathematics also played a great role in the development of Jaina Karmic theory.[45] So it may be envisaged that Jaina astronomical system is, indeed, a compendimum of knowledge amassed through belike a long tradition following the course of Jaina Philosophy. However, Jaina School of astronomy was established in its true perspectives in the post-Vedāṅga pre-Siddhāntic period in the history of ancient Indian Astronomy.

5. Vedāṅga Jyotiṣa has often been dated to twelfth century B.C.[24] on the basis of the position among the nakṣatras (asterisms) that it assigns to winter solstice. In Vedanga Jyotiṣa period, Winter solstice occurred in Dhaniṣṭhā (β Delphini).[24] Mahābhārata gives the position of Winter solstice in Śravaṇa (α Aquilae) and the relevan text has been assigned a period about 450 B.C.[25] According to Jaina canon, Winter solstice coincided with Abhijit (α Lyrae).[23] Besides, Sûrya Siddhānta (system of the sun), one of the earliest sou ces of Siddāntic astronomy, was probably written about 400 A.D.[54] or fifth century A.D.[56] But the old Sūrya Siddhānta is assigned to about 200 B.C.[24] So Jaina canonical texts may be tentatively assigned to a period from 450 B.C. to 200 B.C. However, according to Boyer,[14] the age of Siddhāntas systems of astronomy followed about the second century A.D. should the period from 2nd century B.C. to 2nd century A.D. be looked upon as a transitional period between Jaina astronomy and Siddhantic astronomy ? Investigations are yet to be made in this field.

6. It may also be noted that no reference has as yet been found to point out that the order of rāśis (signs) began from a sign other than Meṣa (sidereal Aries) or the Meṣa sign began from a nakṣtra (asterism) other than Aśvinī (β Arietis). There is no doubt that these terms denoting ecliptic signs were not current in Vedāṇga Jyotiṣa period. Probably these terms came into vogue when Vernal equinox occurred in Aśvinī (α Arietis) nakṣatra (asterism) and Meśa sign (sidereal Aries) at that time. The tropical longitude of the star β Arietis, the identifying star of Aśvinī, was 31°53′ and that of α Arietis, 35°34′ in 18.0 A.D. Hence the years when the tropical longitudes of these stars were zero can be worked out, taking 72 years for 1° precession, as follows :

$31°53' \times 72\ (=2296) - 1850 = 446$ B.C.

and $35°34' \times 72\ (=2561) - 1850 = 711$ B.C.

The mean of these dates is 579 B.C. This value is 201 B C. Vide Fig No. 11-1 as adapted from RCRC.

MAGNITUDES

First ●

Second ●

Third •

Fourth •

Fifth •

SIDEREAL POSITIONS OF THE FIRST POINT OF ARIES (γ) IN DIFFERENT TIMES

M=Modern 1976 A.D.

A=Zero point of Aśvini nakṣatra 285 A D.

Pt=Ptolemy 150 A. D.

H=Hipparchus 140 B C.

J=Jaina period* 201 B. C.

*Period of occurrence of Winter solstice when sun's longitude used to be equal to that of beginning of Abhijit which is 630 muhūrtas (=270°47′) from Aśvinī nakṣatra.

Fig. No. 11-1. *The Zodiac through ages. (Adapted from RCRC)*

Since Winter solstice in Abhijit (α Lyrae) corresponds to Vernal equinox in Aśvinī (β Arietis), probably it was the period when reckoning of first point of the zodiacal circumference was shifted from Winter solstice to Vernal equinox. Thus in the light of this discussion, the probable period of Jaina canon may be assigned to about sixth century B. C.

It is worthy of note that nakṣatra system and not the ecliptic signs, and the Vedic quinquennial yuga theory were still held in esteem. There is no trace of Greek epicyclic theory in Jaina canon. It seems contemplable that Sūrya prajñapti may be assigned to a stage of Indian astronomy which was not yet influenced by the astronomical science of the Greeks [51] However, the degree of diffusion of knowledge between East and West is still an unsettled matter.[56] It may be concluded that the subject matter of Jaina canonical literature had gone on accumulating since long and it developed gradually during the course of several generations[52] starting from the firm establishment of the order and monastic life. According to Winternitz,[53] the earliest portions of Jaina canon might probably belong at the latest to the second century after Mahāvīra's death, the period of the Maurya Candragupta, in which tradition places the council of Pāṭlīputra, whilst the latest portions may be dated nearer to the council of Valabhī under the presidency of Devardhi. However, evidences are wanting in the embodiment of this dissertation to prove in an infalliable manner that Jaina astronomical system promulgates a pronounced advancement over Vedāṅga Jyotiṣa and it paves the way towards the development of Siddhāntic astronomy The confusion due to some resemblances between Vedāṅga Jyotiṣa and Paitāmaha Siddhānta (system of Paitāmaha) whose epoch is A.D. 80, has been eradicated. Thereby in the light of diversity of opinions about the antiquity of periods of Vedāṅga Jyotiṣa and Siddhāntic astronomy, the extents of the glorious period of Jaina School of astronomy may be a minori ad majus assigned to post-Vedāṅga pre-siddhāntic period in the history of ancient Indian astronomy.

1.2 SOME OTHER JAINA NON-CANONICAL AND SOME NON-JAINA ALLIED WORKS

There are some Jaina and non-Jaina works other than Jaina canonical texts, which are of much interest for studies in Jaina

School of Astronomy. A brief account of their antiquity is given as follows : –

1. *Jambūdīva Paṇṇatti Saṅgaho* (=*JPS*) of Paūmaṇandin, edited by A. N. Upadhye and Hira Lal Jain (Sholapur, 1958).

According to the editors, the earliest manuscript of JPS, known to us, is that from Āmera and it is written in 1518 B.S (1461 A.D.) The JPS seems to be indebted to a number of earlier works some of which belong to an authentic authorship and date, like the Mūlācāra, Tiloya-Paṇṇatti, Bṛhatkṣetrasamāsa and Trilokrsāra (=TS). The TS of Nemichandra is to be assigned to the tenth century A.D. Thus it may be concluded that JPS was composed after tenth century A D., the date of TS, and before 1461 A. D., the date of Āmera manuscript. The editors opine that Padmaṇandin (or Paûmaṇandin) might have composed the JPS about 1000 A.D [26]

2. *Tiloya-Paṇṇatti* (in Sanskrit, Triloka Prajñapti) (=TP) Part I (second edition 1956) edited by A.N. Upadhye and Hira Lal Jain;

   Part II (first edition 1951) edited by H. L. Jain and A.N. Upadhye.

According to Upadhye,[27] the TP is to be assigned to some period between 473 A D. and 609 A.D. However, the work may have acquired its present form as late as about the beginning of the ninth century.[28] Hira Lal Jain places it between 500-800 A D.[29] However, the fixing of date of Yativṛṣabha, the author of TP, is yet to be ascertained

3. *Tattvārthādhigama Sūtra* (=TDS) of Umāsvāti.

   Hindi commentary by Khubachandra (Bombay, 1932).

According to the M.L. Mehta,[31] the author of TDS was Umāsvāti (circa 135-219). According to J P Jain,[31] the data of Umāsvāti (or Umāsvāmīn) is about 40-90 A.D. and about the first half the first century A.D., according to some others.[32] Nathuram Premi[33] assigns the TDS (manual about for the understanding of the true nature of things) to about fourth or fifth century A.D.

4. *Bhadrabāhu Sanhitā*. Edited with Hindi commentary by Nemichandra Shastri (Kashi, 1959).

Bhadrabāhu, the author, belongs to a period of about 313 B.C.[16] There was also an earlier Bhadrabāhu (468 or 467 B.C.) to

whom is ascribed Kalpa Sūtra as contained in the Daśaśrutaskandha, one of the six Chedasūtras.[34]

5. *Arthaśāstra* of Kauṭilyā, 3 Vols. Edited with translation by R. P. Kangle (Bombay, 1960-65).

Many scholars have indentified the author Kauṭilya with the minister of king Candragupta Maurya who established Mauryan Empire in northern India shortly before 300 B.C. However, Pingree adds that the book two of the present recension of Arthaśāstra does not antedate the second century A.D. (see T. R. Trautman, Kauṭilya and the Arthaśāstsa. Leiden, 1971).[18]

6. *Ṛṣṭasamuccya śāstra* of Durgadevācārya, Edited by Jin Vijay Muni and A.S. Gopani (Bombay, 2001 B.S.).

According to the editors, the date of Durgadeva is about eleventh century A. D. but the identity of the author as regards which Durgadeva, is yet to be investigated.[35] Nemichandra Shastri assigns him to 1032 A.D.[36]

7. *Gaṇitānuyoga* (=GA). Compiled by Muni K. L. Kamal with Hindi translation by M. L. Mehta (Sanderao, 2496 V. S.).

As we have seen earlier that Gaṇitānuyoga denotes a class of Jaina canonical literature. Here the GA denotes a compilation of geographical and astronomical abstracts from the Jaina canonical texts. The GA is a secondary source.

8. *Manu Smṛti*. Hindi commentary by Keshva Prashad Sharma Dvivedi (Bombay, 1975 B.S.).

According to Bühler,[43] the work as it is known to us existed in the second century A. D.

9. '*Lokavibhāga*' of Sinhasura. Edited by Balchandra Siddhantashastri (Sholapur, 1962).

According to the editor,[20] Lokavibhāga belongs to a period not earlier than that of Trilokasāra (tenth century A.D.). He defies any attempt to associate this work with Sarvanandī (515 B. S) who had composed a work that has become extinct by this time.

10. *Gaṇitasāra-saṅgraha*. Edited with a Hindi translation by L.C. Jain (Sholapur, 1963).

Mahāvīrācārya (c. 850 A.D.), the author of Gaṇitāsara Saṅgraha, was a contemporary of Nṛpatunga of Amoghavarṣa (815-877 A. D.) of the Rāṣṭrakūta dynasty in the history of south India.[68]

11. *Trilokasāra* of Nemicandra. Edited with Sanskrit commentary of Mādhava Candra by Manohar Lal Shartri. (Bombay, 2444 V.S.)

The Trilokasāra of Nemichandra is to be assigned to the tenth Century A.D.[69]

12. *Jyotiṣa Karaṇḍaka* (=*JK*), Sanskrit commentary by Malaya Giri. (Ratlam, 1928).

According to K. S. Raghavan[47], JK was written as a guide to Sūrya Prajñapti in 514 A.D. But according to N. C. Shastri,[71] JK is an original work and on the basis of linquistic survey, he assigns it to a period of 300–400 B.C.

CHAPTER II

Units of Time, Length and Graduation of Zodiacal Circumference

2.1 TIME UNITS IN ANCIENT INDIAN ASTRONOMY

This section renders a simple probe into the diversity of time-units in ancient Indian astronomy. Light is thrown upon the probable course of independent emergence of Sexagesimal system of time-units in India.

It was quite natural that ancient people had felt the need for measurement of equal intervals of time. The ancient Sumerians divided the day into three unequal watches down to medieval time.[1] The ancient Babylonians had divided the nychthemeron (day and night) into twelve hours of thirty gesh each, gesh being equal to four minutes; the Egyptians had divided the day and the night into twelve hours each and later in medieval times, the twenty-four-hour division for the whole day (day and night) was adopted.[2] The day (period between sunrise and sunset) used to be divided into two, three, four, five and fifteen parts in ancient India.[3] In Atharva-Veda Jyotiṣa[4] (=AJ) each of the day and the night is divided into fifteen parts called muhūrtas But Taittirīya Brāhmaṇa (TB. 3.10.1)[5] gives a different nomenclature of muhūrtas in the day and the night of the bright and the dark lunar halves respectively.

It may be remarked that division of the day (day light) and the night into fifteen parts each implies that one part measured different lengths of time on different days and different nights. Lengths of the day and the night vary throughout an year but the length of an ahorātra (day and night) remains constant. Thus the whole day (day and night) as Dixit[6] also opines, must have been divided into thirty divisions as the month is divided into thirty parts. Such a 30-fold division of an ahorātra (day and night) must have impregnated the primordial concept of a standard 'muhūrta' (=48 minutes) which no longer denoted a different

length of time on different days. Thus the need for corroborating the physical concept of standard 'muhūrta' as the unit of time might have necessitated the usage of devices like gnomon, water clock etc. for this purpose. One such gnomonic text (where shadow-lengths are given at the respective ends of fifteen muhūratas in a daylight) as contained in AJ leads on analysis to conclusion that the AJ gnomonic experiment was devised to standardize 'muhūrta' as 1/15th part of an Equinoctial day.[9] Many ancient works like Śatapatha Brāhmaṇa,[59] manu Smṛti and Vedāṅga Jyotiṣa make an explicit reference to thirty standard muhūratas in a day (day and night). However, according to Jaina canonical works, an ahorātra (day and night) has been categorically divided into thirty muhūrtas. JP.8 6 states as : (Quotation No. 2.1-1).

i.e., "How many muhūrtas are there in an ahorātra (day and night) ?

There are thirty muhūrtas, viz.

Raudra, Śveta, Mitra, Vāyu, Suvītā, Abhicandra, Mahendra, Balawāna, Brahmā, Bahusatya, Īśāna, Tvaṣṭā, Bhavitātmā, Vaiśramaṇa, Varuṇa, Ānanda, Vijay, Viśvasena, Prajapatya, Upaśama, Gandharva. Agniveśa, Śatavṛṣabha, Ātmāvā, Amama, Kraṇavama. Bhauma, Vṛṣabha, Savārtha, Rākṣasa."

Other explicit references are :

i. SP.10.3

ii. SVS.30.3

There had been much diversity of the relation between muhūrta and other sub-multiple units of time. In this context, Vedāṅga Jyotiṣa (=VJ), Rk. recension, verse 16, states : (Quotation No 2.1-2).

i. e. "10½ kalās make one nāḍikā, two nāḍikās make one muhūrta and 30 muhūrtas or 603 kalās make one day."

This may be tabulated as follows :

TABLE 2.1-1

THE VJ UNITS OF TIME

$10\frac{1}{20}$ kalās	=1 nāḍikā
2 nāḍikās	=1 muhūrta
30 muhūrtas	=1 day (day and night)

The Śatapatha Brāhmaṇa (=SB), a work of pre-Vedāṅga Jyotiṣa period, gives a different account of time-units shown in the following table :[59]

TABLE 2.1-2
THE SB UNITS OF TIME

15 prāṇas	=1 idānī
15 idānīs	=1 itri
15 itris	=1 kṣipra
15 kṣipras	=1 muhūrta
30 muhūrtas	=1 day (day and night)

According to Viṣṇu Purāṇa[18] (ViP. 3.6-10), the time-units are tabulated as below :

TABLE 2.1-3
THE ViP UNITS OF TIMES

Time taken to pronounce a letter	=1 nimeṣa
15 nimeṣas	=1 kāṣṭhā
30 kāṣṭhās	=1 kalā
15 kalās	=1 nāḍikā
2 nāḍikās	=1 muhūrta

According to Vāyu Purāṇa[11] (=VP), the time-units are reproduced in the following table :

TABLE 2. -4
THE VP UNITS OF TIME

15 nimeṣas	=1 kāṣṭhā
30 kāṣṭhās	=1 kalā
30 kalās	=1 muhūrta

A similar account stated in Manu Smṛti[65] (MS.1.64) is tabulated as below : (Quotation No. 2.1-3).

TABLE 2.1-5
THE MS UNITS OF TIME

i.e.	
"18 nimeṣas	=1 kāṣṭhā
30 kāṣṭhās	=1 kalā
30 kalās	=1 muhūrta
30 muhūrtas	=1 ahorātra (day and night)"

The AJ units of time are tabulated as below : [4,10]

TABLE 2.1-6
THE AJ UNITS OF TIME

12 nimeṣas (blinking of eye)	=1 lava
30 lavas	=1 kalā
30 kalās	=1 truṭi
30 truṭis	=1 muhūrta
30 muhūrtas	=1 ahorātra (day and night)

Besides, according to Dr. L. Sibaiya,[18] one nimeṣa is equal to $\frac{27}{125}$ seconds.

$\therefore$ 1 muhūrta (48 minutes) $= \frac{40,000}{3}$ nimeṣas

But on the other hand, we have

1 muhūrta = 324,000 nimeṣas (AJ units)
= 162,000 nimeṣas (MS units)
= 135,000 nimeṣas (VP and ViP units)

Similarly it may be easily seen that

1 muhūrta = 900 kalās (AJ units)
= 30 kalās (MS, VP and ViP units)
= $20\frac{1}{10}$ kalās (VJ units)

A similar trend is also exhibited in interrelationship of the subdivisions of a nimeṣa. Alberūnī[14] mentions that according to some of the Hindus,

2 truṭis = 1 lava
2 lavas = 1 nimeṣa,

but according to some others,

8 trutis = 1 lava
8 lavas = 1 nimeṣa

In the light of foregoing discussion, it is evident that there existed a great diversity of units of time in Vedic times. A unit called by a single name measured different lengths of time.

Now let us make a probe into the concept of the smallest Vedic unit of time, 'paramāṇu kāla' (atom time). Paramāṇu kāla (atom time) is related with a nimeṣa as follows[14] :

TABLE 2.1-7
THE VEDIC SUB-MULTIPLE UNITS OF A NIMEṢA

2 paramāṇus (atoms)	= 1 aṇu (molecule)
3 aṇus	= 1 trasareṇu
3 trasareṇus	= 1 truṭi
100 truṭis	= 1 vedha
3 vedhas	= 1 lava
3 lavas	= 1 nimeṣa

Therefore, 1 nimeṣa = 16200 paramāṇus ('atoms' of time)………(2.1-1)

Now to get the least length of paramāṇukāla (atom time), we may consider the system of AJ units of time because the number of AJ nimeṣas in a muhūrta is greater than its counterpart in any other system of time-units. So using eq. No. (2.1-1). we have

1 muhūrta (48 minutes) = 324000 nimeṣas (AJ units)
= 324000×16200 paramāṇukālas (atoms times)

$\therefore$ 1 paramāṇukāla (atom time) $= \frac{1}{1822500}$ second ……(2.1-2)

$= 1.8 \times 10^{-6}$ second approx.

However a separate account[15] is also found that an atom (truṭi ?) of time was regarded as equal to 1/303750 of a second,

i.e. 1 atom (truṭi ?) of time $= \frac{1}{303750}$ second ……… (2.1-3)

Comparing eq. No. (2.1-2) and eq. No. (2 1-3),, we have

1 atom (truṭi ?) of time =6 paramāṇukālas (atom times)

But from table (2.1-7), we have

1 truṭi	=18 paramāṇukālas (atoms times),
and	
1 trasareṇu	=6 paramāṇkālas (atoms times)

Therefore it appears that an atom (truṭi ?) of time as referred to above represents probably a trasareṇu (6 paramāṇus or atoms) of time). This atom (truṭi ?) of time represents a truṭi iff trasareṇu might have been dropped by some sort of interpolation in due course of time. It is however erroneous to presume an atom (=truṭi)[15] because atom and truṭi are not synonymical at all.

Now let us peep into the definition of paramāṇukāla, literally an atom of time. According to Mīmānsakas, paramāṇukāla is defined as the time taken by an atom to cross a distance of its own size. The size of paramāṇu underwent several changes from time to time Here it is worthy of note that according to Jaina's concept, an electron, the fundamental particle of the modern atom, is infinitely more gross than a paramāṇu (atom, literally).[57] So it appears that paramāṇukāla in a broader sense, denoted the smallest interval of time and therefore it represented different lengths of time at different times in accordance with the respective concepts of length of a paramāṇu. A detailed discussion of the length of paramāṇu (atom) is however out of scope of this work.

Besides. according to Jaina canonical texts, 'samaya' (time, literally) is the smallest indivisible part of time.[58] Samaya-unit of time is related with other Jaina units of time as shown in the following table :[59]

TABLE 2.1-8
THE JAINA UNITS OF TIME

The smallest part of time	=1 samaya (time, literally)
Jaghanya-yukta-asaṅkhya samayas	=1 āvalikā
$4446\frac{2458}{3773}$ āvalikās	=1 prāṇa (breath)
7 parāṇas	=1 stoka

7 stokas	=1 lava
38½ lavas	=1 ghaṭī
2 ghaṭīs	=1 muhūrta
30 muhūrtas	=1 ahorātra (day and night)
30 ahorātras	=1 māsa (month)
12 māsas	=1 varṣa (year)

It may be easily computed that

1 muhūrta =16777216 āvalikās ....(2.1-4)

It is worth-mentioning here that according to Jaina canon,[16] the counting of numbers has been divided into three categories, viz.

1. Saṅkhyāta (measurable)
2. Asaṅkhyāta (non-measurable but not infinite)
3. Anants (infinite).

Each category has been further divided into three sub-categories, viz.

1. Parīta
2. Yukta
3. Asaṅhhyāta

Each sub-category has been furthermore divided into three sub-categories, viz.

1. Jaghanya
2. Madhyama
3. Utkṛṣṭa

By definition[16] Jaghanya-yukta-asaṅkhyāta (=j) samayas make an āvalikā, Muni Mahendra Kumar II in his book entitled Viśva Prahelikā[17] has computed that the least value of 'j' is almost equal to

$$\sim 1.469 \times 10^{103}$$

Thus eq. No. (2.1-4) may be written

1 muhūrta (48 minutes) =16777216 j samayas

$$\therefore \quad 1 \text{ samaya} = \frac{48 \times 60}{16777216 \times (7.58 \times 10^{103})^{(7.58 \times 10^{103})^{\cdot^{\cdot^{(7.58\times 10^{103})^{(7.58 \times 10^{103})}}}}}} \text{ second}$$

$$= 1.7164 \times 10 \qquad \text{second approx.}$$

Thus compared with eq. No (2.1-2), it is evident that a samaya-unit of time is much smaller than unit paramāṇukāla.

Still it is to be investigated how the number of āvalikās in a muhūrta was obtained. But the fact that $4446\frac{2458}{3773}$ āvalikās make a prāṇa (breath) suggests that it may be speculated that a muhūrta might have been equal to 3773 prāṇas (breaths) according to one system and equal to 16777216 āvalikās according to the other system of time-units. When these two systems inrermingled, 3773 prāṇas were equated with 16777216 āvalikās. Otherwise the division of a prāṇa (breath) into $4446\frac{2458}{3773}$ āvalikās makes no sense, albeit inadequate, for the choice of this number. However it is desirable to pursue a deep study of all systems of time-units and respective traditions varying from time to time and place to place that might give a clue to how these figures were actually generated.

Now we may also have a glance at systems of time-units in Siddhāntic texts. Exempli gratia, Āryabhaṭa (476 A. D.) gives in his Āryabhaṭīyam a separate account of time units reproduced as below :[18]

TABLE 2.1-9
TIME UNITS IN ĀRYABHAṬĪYAM

Time taken to pronounce 60 guru akṣaras (letters)	=1 vināḍikā (24 seconds)
60 vināḍikās	=1 nāḍikā (24 minutes)
60 nāḍikās	=1 ahorātra (day and night

However Sūrya Siddhānta[67] (1.11-12) and also Brāhma Sphuṭa Siddhānta[64] (=BSS) of Brahmagupta (c. 628 A D.) give a slightly different description of time units reproduced as below :

TABLE 2.1-10
TIME UNITS IN BSS

6 prāṇas (breaths) or asus	=1 nakṣatra-vināḍikā or pala (24 seconds)
60 palas	=1 nāḍikā or ghaṭikā (24 minutes)
60 ghaṭikās	=1 divasa (day and night)

Evidently a system of 60-fold division of each unit was generally employed in Siddhāntic texts.

(a) *DISCUSSION*

There was a great diversity of time-in ancient India. One may however ponder that the AJ units of time (see table 2.1-6) exhibit a unique system of time-reckoning such that every unit is sub-divided into thirty equal parts. This way of time-reckoning may be conveniently called 'Trigesimal system.' A glimpse of Trigesimal system may also be seen is MS, VP and ViP units of time. The popular notion among modern Hindus that a month consists of thirty ahorātras (day and nights) seems to be due to the residual effect of this system. This notion was also prevalent in Vedāṅga Jyotiṣa period (see table 2.1-1). It appears that the division of an ahorātra (day and night) into thirty muhūrtas might have induced the idea to divide a muhūrta into thirty equal parts and so on. Thus the VJ units of time might have paved the way towards the development of Trigesimal system extant in AJ units. The Jaina units of time also partly imply this system and the VJ relation that two nāḍikās (ghaṭīs' make a muhūrta (48 minutes) is again revived therein. Thus an ahorātra (day and night) consists of thirty muhūrtas or sixty nāḍikās or ghaṭīs. Here it is worth-mentioning that the Jaina relation between a muhūrta, āvalikās and samayas exhibits their tendencies towards sharpness in time-measurements. Probably because of such tendencies Jainas of later pre-Siddhāntic period might have been tempted to revive the Vedic tradition that an ahorātra (day and night) was divided into sixty ghaṭīs. Consequently a ghaṭī might have been divided into sixty equal parts and so on. The new system popularly known as Sexagesimal system, came into existence in due time at the fag end of pre-Siddhāntic period and it became current in Siddhāntic period.

However it is our conjecture that some peculiar notions among the Jainas had also made their own contribution to the probable emergence of Sexagesimal system in this manner. Jainas had conceived two suns each describing half the diurnal circle in an ahorātra (day and night) or thirty muhūrtas, to describe the complete diurnal circle.[19] Therefore either sun would take sixty muhūrtas to describe the complete diurnal circle. With the disappearance of notion of two suns, the only sun described the diurnal circle in sixty

ardha-muhūrtas (half-muhūrtas). Here it may be noted that the trignometrical modern sine is actually used in place of Indian half-sine[7] and the word 'half' must have dropped out because of its repeated use. As an analogy, Girija Prasad Dvivedi opines tnat a yojana actually denoted half a yojana [20] It is to be emphasized here that the use of ardha-units (half-units) had once become a tradition. The use of ardh-units (half-units) is also justified on the ground that the user by inspection takes always upto half graduation division. Thus the impoitance attached to ardhamuhūrta (half-muhūrta) was probably preserved in calling it by the VJ equivalent nāḍikā latter called ghaṭī (=24 minutes). So the tradition of division of an ahorātra (day and night) into sixty ghaṭīs was probably followed in subsebuent sub-division of a ghaṭī into sixty palās and so on. Thus Sexagesimal system of 60-fold division of each unit of time was developed. However some more investigations are yet to be made in corroborating the proneness of such an evolutionary development of the transitional period between the decline of Jaina astronomy and the advent of Siddhāntic astronomy are yet to be traced in the lap of the time. Some works of Jaina canon have also become extinct sine die. Still we have not gone much beyond speculation.

Now the AJ units of Trigesimal system may be compared with those of the Sexagesimal system as follows :

TABLE 2.1-11
TIME-UNITS OF TRIGESIMAL AND SEXAGESIMAL SYSTEMS

Trigesimal system	Sexagesimal system
1 muhūrta (30 truṭis)	=2 ghatis or 120 palas
1 truṭi (30 kalas)	=4 palas or 240 vipalas
1 kalā (30 lavas)	=8 vipalas or 480 prativipalas
1 lava	=16 prativpalas or 8/75 second

Thus the smallest practical time-unit of Sexagesimal system, prativipala (1/150 second) is comparatively sixteen times smaller than lava, the smallest time-unit of Trigesimal system.

Now a passing reference may be made to the antiquitic development of the Sexagesimal system. It is generally considered to

have been developed by the Sumerians (origional dwellers of Babylon) and their successors in Mesopotamia.[21] Besides, in China the adherents of the Saufen calender also made use of the Sexagesimal signs in the first century B.C.[22] It cannot, of course, be clāimed with certainty as to how far the number sixty of nāḍikās in an ahorātra (day and night) as depicted in VJ (see table 2.1-1) can be taken as the first sign of Sexagesimal system in India. But irrespective of any covetousness of the prestige of ancient Indian heritage, a cosmopolitan mind will approbate the view that some sort of Trigesimal system remained in vogue over a large period in ancient India. It seems contemplable that Trigesimal system gradually emerged into Sexagesimal system. The probable role of Jaina astronomical system in the course of such developments cannot be inundated in all.

Besides, it may be worth mentioning here that like Rig Vedic tradition, Jainas also regarded kāla (time) as ever turning wheel with neither beginning nor end. There are two broad sub-divisions of time i.e., avasarpinī kāla and utsarpiṇī kāla; the former is the descending half of the time wheel whereas the latter corresponds to its ascendding half. Each half is further divided into six smaller periods, viz. suṣma-suṣma, suṣma, suṣma-duṣma, duṣma-suṣma, duṣma and duṣma-duṣma.[65] The author leaves the problem of time-concept in Jaina mythology for the students of philosophy.

2.2 LENGTH UNITS IN JAINA ASTRONOMY

Man's nature has always been relevant to religion and cosmic phenomena. It was customary among ancient Chinese that several astronomical changes were accorded with the advent of any new regime.[22] Apropos such traditions length-units had also undegone a multitude of alterations at saveral places in ancient times and it took couples of centuries before they were finally fixed. Exempli gratia, king Henry I of England had decided that the standard yard should be the length of his arm but in the reign of Edward II, a new law said that one inch should be the length of three grains of barley, end to end.[23] In India, Hamanyun had ordered the length of a yard to be equal to the sum of diameters of forty-two Sikandari coins or forty-two fingerwidths. Akbar settled his Ilahi gaz (divine yard) for forty-one finger-widths which worked out to be 29.63 inches; but with the advent of British influence over India, the Ilahi gaz (divine yard) was fixed at thirty-three inches.[24] How-

ever, the old Scotch mile was 1.127 and the old Irish mile was 1.273 times the length of the present British mile.[25] It was not until 1878 when the exact length of a yard, 1760 yards making a mile, was finally fixed.[23] Likewise a cubit measured different lengths in different nations, e.g.

Egyptian Royal cubit	=20.63 inches
Greek Olympic cubit (25 digits)	=18.23 inches
Sumerian cubit	=19.50 inches

Likewise in different parts of ancient India, there was a great diversity of measures of length. It is no less than a surprise that the variations in the lengths of Indian kosa most have puzzled the Chinese pilgrims and perhaps that is why FA-hian[26] (399-413 A.D.) used the Indian measure 'Yojana' whilst Hwen-thsang[26] (629-645 A.D.) used his native measure 'Li'. Here a simple probe is rendered into the mystery of conspicuity of systems of length-units as propounded in Jaina canonical literature. The complexity of relation between a yojana and the number of British miles is also revealed in the same context.

(*a*) *Description of Units of Length*

Aṅgula (finger-width) was used fundamentally as a prominent unit of length in ancient India; multiple and sub-multiple units were derived from it. The earliest use of an aṅgula (finger-width) seems to have been made in Atharva Veda Jyotiṣa where the shadow-lengths of a śaṅku (gnomon have been recorded after every muhūrta in integral numbers of aṅgulas.[4,27] Hower, the primaeval record of three different magnitudes of an aṅgula (finger-width) is found in Anuyogadvāra Sūtra (=ADS), a Jaina canonical text. ADS. 149.12 states : (Quotation No. 2.3-1)

> i.e. There are three kinds of an aṅgula (finger-width),
> viz. ātamāṅgula, utsedhāṅgula (and) pranāṇāṅgula."

A linear measurement of an aṅgula is called sucyaṅgula except that in case of pramāṇāṅgula it is termed as śreṇyāṅgula. Pratarāṅgula and ghānāṅgula denote a square aṅgula and cubic aṅgula respectively. The linear measure of an aṅgula have been explicitly stated in ADS given as follows :

(1) *ĀTAMĀṄGULA* : ADS. 149.13.1 srates as : (Quotation No. 2.2-2)

i.e. "Twelve aṅgulas of a person make one's face-length, nine times the face-length equals the length of puruṣa (person)."
So the finger-width of the person is called an ātmāṅgula.

(2) *UTSEDHĀṄGULA* : ADS.149.23 states as : (Quotation No. 2.2-3)

i.e. "Every great emperor possesses a kākanīratna (a piece of gem) of eight Souvarṇikas (weight-measure), of the size of a cube having six surfaces, twelve edges and eight diagonals. Every side of this (cube) is one utsedhāṅgula long. It is equal to half the length of an aṅgula (finger-width) of lord Mahāvīra. One thousand times of it (utsedhāṅgula) is (the length of) one pramāṇāṅgula."

However, utsedhāṅgula is also defined in terms of its submultiples. ADS.149.23 states : (Quotation No. 2.2-4).

TABLE 2.2-1
THE ADS UNITS OF LENGTH

i.e.	
"Infinit paramāṇu-pudgalas	=1 ussaṇhasaṇihayā
8 ussa. units	=1 saṇhasaṇihayā
8 saṇha. units	=1 ūrdhvareṇu
8 ūrdh.	=1 trasareṇu
8 trasa.	=1 ratharenu
8 ratha.	=1 devakurū bālāgra (hair's point)
8 deva. bālāgras	=1 harivarṣa bālāgara
8 hari. bālāgaras	=1 hemvat bālāgra
8 hem. bālāgaras	=1 videhakṣetraja bālāgra
8 videha. bālāgras	=1 bhāratakṣetraja bālāgra
8 bhārata. bālāgras	=1 likṣā (līkha or mini louse)
8 likṣās	=1 yūka (louse)
8 yūkas	=1 yavamadhya
8 yavamadhyas	=1 utsedhāṅgula."

(3) ***PRAMĀṆĀṄGULA*** : The length of one pramāṇāṅgula is one thousand times the length of an utsedhāṅgula, as depicted above (See quot. No. 2.2-3).

The various aṅgulas are thus inter-related as fol'ows :

1 utsedhāṅgula	$=\frac{1}{2}$ ātmāṅgula
1 pramāṇāṅgula	=1000 utsedhāṅgula
1 pramāṇāṅgula	=500 ātmāṅgulas
	=1000 utsedhāṅgulas......(2.2-1)

This reflects upon the existence of three different systems of length-units and they may be called accordingly as :

(1) Ātma system

(2) Utsedha system

(3) Pramāṇa system.

These three systems had an alike nomenclature of length-units. In each case the practical unit was a yojana whose relation with an aṅgula (finger-width) is given in the following table :[28]

TABLE 2.2-2
THE ADS UNITS OF LENGTH, CONTD.

6 aṅgulas (finger-widths)	=1 pāda (length of human foot)
2 pādas	=1 vitasti (span)
2 vitastis	=1 ratni
2 ratnis	=1 kukṣi
2 kukṣis	=1 dhanuṣa (bow)
2000 dhanuṣas	=1 gavyūti
4 gavyūtis	=1 yojana

It can be easily computed that

1 yojana	=768000 aṅgulas .. ..(2.2-2)

Thus according to three different systems of length-units, we have

1 ātma yojana	=768000 ātmāṅgulas
1 utsedha yojana	=768000 utesedhāṅgulas
and 1 pramāṅa yojana	=768000 pramāṇāṅgulas.

∴ On using eq. No. (2.2-1), we have

1 pramāṇa yojana	=500 ātma yojanas
	=1000 utsedha yojanas......(2.2-3)

In a more general form, it may be easily seen that

1 pramāṇa unit =500 ātma units

=100 utsedha units......(2.2-4)

Now we may also peep into some other allied works containing some accounts of linear measures of length. According to Tiloya Paṇṇati (=TS) of Jadivasaha (Yativṛṣabha), units of length (see TP.1.93-132)[29] are reproduced below :

TABLE 2.2-3

THE TP UNITS oF LENGTA

Infinitely many paramāṇus	=1 avasannāsanna skandha
8 avasa. units	=1 sannāsanna skandha
8 sannāsannas	=1 truṭareṇu
8 truṭareṇus	=1 trasareṇu
8 trasareṇus	=1 rathareṇu
8 rathareṇus	=1 uttama bhogahūmi bālāgra
8 ut. bho. bālāgras	=1 madhyama bhogabhūmi bālāgra
8 ma. bho bālāgras	=1 jaghanya bhogabhūmi bālāgra
8 ja. bho bālāgras	=1 karma bhūmi bālāgra
8 ka bālāgras	=1 likṣa
8 likṣas	=1 yūka (louse)
8 yūkas	=1 yava (barley corn)
8 yavas	=1 aṅgula (finger-width)
6 aṅgulas	=1 pāda (length of human foot)
2 pādas	=1 vitasti (span)
2 vitastis	=1 hasta (fore-arm or cubit)
2 hastas	=1 rikku or kiṣku
2 kiṣkus	=1 daṇḍa (staff) or dhanuṣa
2000 daṇḍas	=1 krośa
4 krośas	=1 yojana

Besides, a typical table of linear measures, according to Pauliśa Siddhānta[30] (=PS), is given below :

TABLE 2.2-4

THE PS UNITS OF LENGTH

8 yavas	=1 aṅgula (finger-width)
24 aṅgulas	=1 hasta (fore-arm or cubit)
4 hastas	=1 daṇḍa (staff)
2000 daṇḍas	=1 kosa
4 kosas	=1 yojana

The Sinddhāntic units of length as used by Śrīpati etc. are shown in a typical table reproduced below :[24]

TABLE 2.2-5

THE SIDDHĀNTIC UNITS OF LENGTH USED BY ŚRĪPATI ETC.

8 trasareṇus	=1 reṇu
8 reṇus	=1 balagra
8 balagras	=1 likṣa or poppyseed
8 likṣas	=1 yūka (louse)
8 yūkas	=1 yava (barley-corn)
8 yavas	=1 aṅgula (finger-width)
12 aṅgulas	=1 vitasti (span)
2 vitastis	=1 hasta (fore-arm or cubit)
4 hastas	=1 daṇḍa (staff)
2000 daṇḍas	=1 kosa
4 kosas	=1 yojana

It can be easily computed here that a yojana contains 768000 aṅgulas (finger-widths) and an aṅgula contains 8 yavas (barley-corns). But compared with other systems of length-units, we have

1 aṅgula $=8^{10}$ trasareṇus (ADS units) ....(see table 2.2-3)
$=8^{9}$ trasareṇus (TP units)...............(see table 2.2-3)
$=8^{6}$ trasareṇus (Siddhāntic units)......(see table2.2-5)

Now two cases arises :

(i) Either 1 aṅgula=constant

∴ On putting,

t_1=trasareṇu (ADS units)

t_2=trasareṇu (TP units)

t_3=trasareṇu (Siddhantic units)

we have

$$8^{10}t_1=8^9t_2=8^6t_3$$

i.e. $t_1 : t_2 : t_3 = 1 : 8 : 8^4$

∴ $t_2=8t_1$

$t_3=8^4t_1$

This suggest that a trasareṇu has three extremely different magnitudes in different contexts But the magnitude of a yojana (=768000 aṅgulas) remains constant. However this view does not seem plausible.

(2) or 1 aṅgula≠constant,

but $t_1=t_2=t_3$,

i e. a trasareṅu has a constant length but a yojana measures different lengths in different systems of length-units

Let y_1=yojana (ADS units)

Y=yojana (TP units)

y_3=yojana (Siddhantic units)

It may be easily computed that

$y_1 : Y : y_3 = 8^4 : 8^3 : 1$

$$\therefore \quad y_1 = 8\,Y \qquad \text{.........(2.2-5)}$$

i.e. y_1 is eight times Y.

It is however worth-mentioning that still a different account of units of length is described in Lalita-Vistara, a Buddhistic work of pre-Christain era. A typical table is reproduced below :[31]

TABLE 2 2-6
THE BUDDHISTIC UNITS OF LENGTH

7 pramaṇu-rajas	=1 reṇu
7 reṇus	=1 truṭi
7 truṭis	=1 vatayana-raja
7 vatayana-rajas	=1 śaśa-raja
7 śaśa-rajas	=1 aidaka-raja
7 aidaka-rajas	=1 go-raja
7 go-rajas	=1 likṣa-raja
7 likṣa-rajas	=1 sarṣapa
7 sarṣapas	=1 yava (barley-corn)
7 yavas	=1 aṅgulī-parva
12 aṅgulī-parvas	=1 vitasti (span)
2 vitastis	=1 hasta (fore-arm or cubit)
4 hastas	=1 dhanuṣa (bow)
1000 dhanuṣas	=1 kosa
4 kosas	=1 yojana

Thus we find on comparison with Jaina units of length (see

table 2.2-2) that a Buddhistic kosa (parallel to Jainian gavyūti) contains 1000 dhanuṣas instead of 2000 dhanuṣas; and a Buddhistic aṅgula (finger-width) contains 7 yavas (barley-corns) intead of 8 yavas (see tables 2.2-1, 2.2-3 and also 2 2-4 and 2.2-5). Besides, it may be easily computed from table (2.2-6) that

1 Budhistic yojana $= 384000 \times 7$ yavas (barley-corns)

But 1 Jaina yojana $= 768000 \times 8$ yavas (see table2.2-2)

$\therefore$ 1 Buddhistic yojana $= \frac{7}{16}$ Jaina yojana..........(2.2-6)

But, on the other hand, it may be speculated that 1000 dhanuṣas make a Buddhistic kosa actually denoting half-kosa, just as the the modern trigonometric sine actually denotes Indian half-sine.[7] Then the relation (2 2-6) may be written as

1 Bundhistic yojana $= \frac{7}{8}$ Jaina yojana

(ADS units, say)......(2 2-7)

Using eq. No. (2.2-5), we have

1 Budhistic yojana $= 7$ Yojanas (TP units) ....(2.2-8)

It may however be contended that the above relation between a Buddhistic yojana and a jaina yojana is empirical only It is desirable to make better probe into Buddhistic units of length extant in Buddhist canonical literature. This is however out of scope of this work.

Now it would also be desirable to have a peep into a separate account of length-units described by Magasthenes (302-292 B. C.) reproduced as below :[21]

TABLE 2.2-7
THE UNITS OF LENGTH AS REPORTED BY MAGASTHENES

24 aṅgulas	=1 hasta (fore-arm or cubit)
4 hastas	=1 dhanuṣa (bow)
100 dhanuṣas	=1 nalwa
10 nalwas	=1 kosa

It may be easily computed that

1 kosa $= 96000$ aṅgulas (finger-widths)

and 1 dhanuṣa (bow) $= 96$ aṅgulas

But according to Strabo,[16] it may be that 100 aṅgulas (finger-widths) instead of 96 aṅgulas, make a dhanuṣa (bow) to presrve centenary scale. Sriniwasiengar[33] also takes one dhanuṣa to be equal to 100 aṅgulas. But as we find that

1 kosa = 96000 aṅgulas or $\frac{768000}{8}$ aṅgulas

or 8 kosas = 768000 aṅgulas

= 1 yojana (see eq. No. 2.2-2)

So according to this exposition, a yojana consists of 8 kosas of 96000 aṅgulas each; thus it seems plausible that a kosa actually denotes half kosa. In the light of this discussion, it would be inconsistent to take one dhanuṣa to be equal to 100 aṅgulas, instead of 96 aṅgulas. While calculating the circumference of Jambūdvīpa, R.C. Gupta[33] has also refuted Srinivas engar's claim However, it is worthy of note here that the same confusion of numbers 96 and 100 also exists in th monetary scale in which we have 2 baraganis or 'twelvers' equal to 1 panchi or 'twenty-fiver'.[26] So could it be speculated that some sort of centenary scale might have remained in vogue sometimes in ancient India ? A similar idea of metric system unifying weights, measures and volumes, also appeared in China as far back as the time of T'aichu calendar reform (104 B.C.).[22] It may be speculated that such empirical notions might have become defunct at their early stages of development.

Incidently it would be apropos to cite one more example of heretical departure from the here-to-fore tradion that one hasta (fore-arm or cubit) contains 24 aṅgulas (finger-widths). In this connection, Arthaśastras[55] referers to a hasta of 28 aṅgulas.

Besides, it is astounding to note that a uniquely admixed account of linear units of length is found is Śulba Sūtras. According to Baudhayana Śulba (1.3-21), a typical table is reproduced as under:[40]

TABLE 2.2-8

THE BAUDHĀYVNA ŚULBA UNITS OF LENGTH

1 aṅgula	=24 aṇus=35 tilas (moles) placed side by side
1 kṣudrapada	=10 aṅgulas (finger-widths)
1 pāda (length of human foot)	=15 aṅgulas
1 prakrama	=2 pādas=30 aṅgulas
1 aratni	=2 prādeśas=24 aṅgulas
1 puruṣa (man-length)	=1 vyāma=5 aratnis=120 aṅgulas
1 vyāyāma	=4 aratnis=96 aṅgulas
1 pṛthā	=13 aṅgulas
1 bāhu (arm)	=36 aṅgulas
1 jānu	=30 or 32 aṅgulas
1 iṣā	=108 aṅgulas
1 akṣa	=104 aṅgulas
1 yuga (yoke)	=88 aṅgulas
1 samyā (the pin of a yoke)	=36 aṅgulas
1 aṅgula	=$\frac{3}{4}$ inch (approximately)

It is evident by inspection that Baudhāyana Śulba presents a sort of concocted account of dispersed units of length. Several length-units are not related in any simple ratio with one another e.g. one pṛthā contains 13 aṅgulas and one bāhu contains 36 aṅgulas but 13 is prime to 36. Some units, of course, seem to be linked with eaeh another, e. g. one iṣā (108 aṅgulas) is three times a bāhu (36 aṅgulas). It is our conclusory opinion that some more investigations are yet to be made in order to ascertain multiplicity of systems of length-units in ancient India.

(*b*) *Relation between a Yojana and the Number of British Miles*

In the light of foregoing discussion, the diversity of relation between a yojana and the number of British miles depends upon the multitudiousness of systems of length-units. Several scholars of repute have expressed their views regarding number of British miles in a yojana. According to Dvivedi,[30] if a yojana actually denoting half-yojana, contains five miles, the diameter of earth

as enunciated by Brahmagupta (c. 628 A.D.) and Bhāskarācārya comes out to be 7905 miles which is very near the actual value 8000 miles ; an actual yojana would contain ten miles. On the other hand, Dvivedi[30] opines that a kosa contains two miles, thereby a yojana contains eight miles. Alberūni[34] also considers a yojana to be equal to eight miles. The distinct value of kosa now in use in India are also worth mentioning here. The Pādaśāhī kosa or Pañjābī kosa being used in north-west India and the Panjab is about $1\frac{1}{4}$ miles ; the kosa of Gangetic provinces is about $2\frac{1}{4}$ miles and the Bundela kosa being used in Bundelkhand and the Hindu provinces to the south of Jamuna and also in Mysore and south India is about four miles.[26] The kosa of Gangetic provinces is traditionally taken as equal to two miles instead of $2\frac{1}{4}$ miles and the same appears to have been used by Dvivedi. Otherwise, using the relation that a yojana contains four kosas, we have

1 Pādaśāhi or Pañjābī yojana = 5 miles
1 yojana of Gangetic provinces = 9 miles
and 1 Bundelkhand yojana = 16 miles

D. A. Somayaji[35] also opines that a yojana contains nearly five miles (Does this yojana denote a Pādaśāhī or Pañjābī yojana ?) Fleet's estimate[36] of the value of a yojana is $9\frac{1}{11}$ miles. Sir John Bellentine[37] has also affirmed the same estimate. According to L. C. Jain,[29] a yojana contains 4545.45 miles, numerically 500 times $9\frac{1}{11}$ miles. Thus if Fleet's estimate and that of Sir John Bellentine refer to a yojana in ātma system (say), *i.e.*

1 ātma yojana $= 9\frac{1}{11}$ miles .... (2.2 – 9)

Using eq. No. (2.2 – 4), we have

1 pramāṇa yojana = 4545.45 miles .... (2.2 – 10)

So it looks as if the same distance being measured in pramāṇa yojanas and ātma yojanas is expressed in miles holding that an ātma yojana contains $9\frac{1}{11}$ miles. Apparently it may seem plausible that if a pramāṇa yojana be taken as equal to 4545.45

miles an ātma yojana becomes equal to $9\frac{1}{11}$ miles and utsedha yojana $4\frac{6}{11}$ miles (see eq. No. 2.2—4). Let us have a close peep into this hypothesis.

The sun while occupying the innermost maṇḍala (sun's diurnal path on Summer solstice day) is 800 Y distant from samatala-bhūmi ('earth having a plane surface' denoting circular area with centre at the projection of pole of ecliptic).[38] Position of the sun while describing the innermost maṇḍala (sun's diurnal path on Summer solstice day) also lies on the periphery of Jambūdvīpa[39] (isle of Jambū tree) of radius[38] equal to 50000 y. Thus on Summer solstice day, the distance D of the sun from the axis of Meru supposed to have been placed at the centre of Jambūdvīpa is given as

D = 50000 y (ātma yojana, ADS units) (say)
= 100 y_1 (pramāṇa yojanas, ADS units) (see eq. No 2.2—4)
= 800 Y (Yojana, TP units) (see eq. No. 2.2—5)

$$\therefore \quad 50000\ Y = 800\ y \text{ or } 1\ y = \frac{8}{500}\ Y \quad \ldots\ldots \quad (2.2-11)$$

However it may be borne in mind that the tentative axis of Meru always remained at a distance equal to the radius of Meru on flat earth, apart from the true axis of earth (for more details, see S 5.2, S 5.3). Radius of Meru on flat earth is given to be 5000 y or 80 Y (using eq No. 2.2—11). Thus the distance between true axis of earth and the sun describing the innermost maṇḍala (sun's diurnal orbit on Summer solstice day) is given as

= radius of Jambūdvīpa — radius of Meru on flat earth
= 800 Y — 80 Y
= 720 Y

On the other hand, we know that celestial distances were in reality measured in terms of corresponding distances projected over surface of the earth.[39,41] Let δmax be the maximum declination of sun. Thus on the Summer solstice day, north polar distance of sun equals the distance of sun from true axis of earth.

$$\therefore \quad 90^0 - \delta_{max} = 720\ Y \quad \ldots\ldots \quad (2.2.-12)$$

And we also know that the sun traversed a distance of 510 Y from

the innermost maṇḍala (sun's diurnal orbit on Summer solstice day) upto the outermost maṇḍala (sun's diurnal orbit on Winter solstice day) and vice versa.[39,41]

$\therefore$ $2\ \delta_{max} = 510\ Y$ ... ... (2.2—13)

Solving eq. No. (2.2—12) and eq. No. (2.2.—13) we have

$\delta_{max} = 23^0.5$ (true value within limits of error due to approximation)

Thus exitus acta probat.

$\therefore$ From eq. No. (2.2—13), we have

$510\ Y = 47 \times 69.09$ miles

$\because$ ($1' = 6080$ ft.

$\therefore$ $1^0 = 69.09$ miles)[42]

$\therefore$ $1Y = 6.37$ miles (actual British road distances)

It may be recalled here that Cunningham[26] has compared various distances recorded by the Chinese pilgrims between prominent places with the actual British road distances and found out that a Yojana is equivalent to 6.7 miles. Thus our derivation of Y to be equivalent to 6.37 British miles seems to be consistent. Thus our supposition implied in relation (2.2—11) stands justified. Exitus acta probat i.e. result proves the act. Now length of Yojana (or yojana) may specifically be defined as :

1 Yojana (TP units), $Y = 6.37$ miles $= 6.4$ miles approx.

1 pramāṇa yojana (ADS units), $y_1 = 8\ Y = 51$ miles approx.

1 ātma yojana (ADS units), $y = \frac{y_1}{500} = .102$ miles $\Big\}$ (Using

1 utsedha yojana (ADS units) $= \frac{y_1}{1000} = .051$ miles $\Big\}$ eq.No. 2.2—4)

It may however be mentioned that in deriving these results, we have employed a notion of measuring celestial distances projected along the circumference of earth, whereas Jainas were admittedly not aware of the roundity of earth. This could be done with the help of a gnomon. For instance, corresponding to sun's position on a particular day, find on earth a station A where noon-shadow-length of gnomon is zero. Similarly, corresponding to sun's position on any other day, find a station B. The celestial distance between two positions of sun may be conveniently equated with the earth distance AB. Thus it may be contended

that notion of flat earth could hardly affect accuracy of such a technique of measuring celestial distances projected along the surface of earth with the help of a gnomon. It is therefore contemplable that a pramāṇa yojana (ADS units) cannot be taken as equal to 4545.45 miles. The practical pramāṇa Yojana (TP units), as we have derived above, is equal to 6.37 or about 6.4 miles. TP is, however, a later work of about fifth or sixth century A.D.[29] but because Y has a close relation with **y** (see eq. No. 2.2—11), it is quite probable that some description like the account of TP units of length might be contained in some missing portion of Jaina cannon.

It is also worth mentioning that according to Cunnigham's[26] findings, a mile is equivalent to 6 Li (Chinese measure of length). This makes a Yojana (=6.7 miles) to be equivalent to about 40 Li. Earlier we were led to believe[40] that distances like radius of Jambūdvipa, 50000 y etc. were measured in units of Chinese 'Li' and the word 'Li' might have been dropped gradually and the word yojana might have come into vogue instead. But in the light of present discussion, these views are perfectly refutable.

(c) *Conclusion* :

In conclusion, it is evident that there existed as per Jaina canon three different systems of measures of length, *viz.* ātma system, utsedha system and pramāṇa system. Correspondingly any length-unit had three different magnitudes (ADS units) related with one another as follows :

1 pramāṇa unit = 500 ātma units = 1000 utsedha units. Besides,

$$1 \text{ ADS unit} = 8 \text{ TP units} = \frac{7}{8} \text{ Buddhistic unit.}$$

This gives us nine different values of the number of British miles in a Yojana (or yojana). The system like that of Siddhāntic units (see table No. 2.2—5, account of bālāgras seems to be mutilated) still further suggests the scope of increase in the diversity of this relation. Besides, the fact that Digambras take one pramāṇāṅgula to be equal to 500 utsedhāṅgulas[43] or 400 utsedhāṅgulas[8], also arises confusion due to the misconception of an ātmāṅgula (see eq. No. 2.2—1). Consequently it seems plausible

that one must heed to different systems of length-units in ancient India before any attempt is made to vindicate the use of any length-unit like an aṅgula and a yojana etc. in any particular context.

2.3 ZODICAL CIRCUMFERENCE AS GRADUATED IN JAINA ASTRONOMY

Luner zodiac of the Rig-Vedic Hindus consisted of 27 nakṣatras[44] (asterisms). Jainas first measured zodiacal stretches of nakṣatras (asterisms) into time degrees and included Abhijit (α Lyrae) nakṣatra (asterism) to account for the discrepancy in lunar motion. This section renders a simple probe into a series of developments of graduating zodiacal circumference into $27\frac{21}{67}$ days of a nakṣatra month (lunar sidereal revolution) and subsequently into $819\frac{27}{67}$ muhūrtas (1 muhūrta=48 minutes) of a nakṣatra month, 54900 muhūrtas of a 5 year cycle and 360 saura days (saura day equals the time taken by sun to move on 1/360th part of zodiacal circle) finally leading to the development of equal amplitude system of nakṣatras (asterisms) when Abhijit (α Lyrae) was again dropped with the advent of Siddhāntic Astronomy.

Here it would be worthy of introduction that Jainas had a peculiar theory[18] of two suns, two moons and two sets of nakṣatras (asterisms) SP. 10.22.1 states : (Quotation No. 2. 3-1).

> "In Jambūdvīpa (isle of Jambū tree) two moons illumined, are illumining and will be illumining. Two suns shone, are shining, and will be shining. 56 nakṣatras (asterisms) viz. 2 Abhijits (αLyrae), 2 Śravaṇas (α Aquilae)......... 2 Uttrāṣāḍhās (σ Sagittarii), occulted, are occulting and will be occulting (two moons)."

Here we need not enter into whatever may be the mystery of the real and counter bodies existent in Jaina Prakrit texts, China, Greece, and ancient Babylon[45] but one will find that actually a single set of nakṣatras (asterisms) constituted the lunar zodiac of Jainas.[46]

(1) Zodiacal stretch (=ZS) of every nakṣatra (asterism) has been expressed in time-units called muhūrtas (1 muhūrta = 48 minutes). In this context JP. 9.8 states : (Quotation No. 2.3-2).

"Abhijit combines with moon for $9\frac{27}{67}$ muhūrtas (1) Śata-

bhiṣā, Bharaṇī Ārdrā, Āśleṣā, Svāti and Jyeṣṭhā (6 nakṣatras) combine (with moon) for 15 muhūrtas each. (2). Three Uttarās, Punarvasu, Rohinī and Viśākhā (6 nakṣatras) combine (with moon) for 45 muhūrtas each. (3). The rest of the 15 nakṣatras (asterisms) combine (with moon) for 30 muhūrtas each. (4)."

A conspicuous view is presented in table No. (2.3-1).

TABLE NO. 2.3-1

TABLE OF NAKṢATRAS (ASTERISMS) AND THEIR ZODIACAL STRETCHES (=ZS) IN TIME UNITS CALLED MUHŪRTAS (1 MUHŪRTA=48 MINUTES)

Sr. No.	*Nakṣatras*	*ZS in muhūrtas*
1.	Abhijit (α Lyrae)	$9\frac{27}{67}$
2.	Śravana (α Aquilae)	30
3.	Dhaniṣṭhā (β Delphini)	30
4.	Śatabhiṣā (λ Aquarii)	15
5.	Purvābhādrapada (α Pagasi)	30
6.	Uttarābhādrapada (γ Pagasi)	45
7.	Revatī (ξ Piscium)	30
8.	Aśvinī (β Arietis)	30
9.	Bharanī (41 Arietis)	15
10.	Kṛttikā (η Tauri)	30
11.	Rohinī (α Tauri)	45
12.	Mṛgaśirsa (λ Orionis)	30
13.	Ārdrā (α Orionis)	15
14.	Punarvasu (β Geminorum)	45
15.	Puṣya (δ Cancri)	30
16.	Āśleṣā (ε Hydrae)	15
17.	Meghā (α Leonis)	30
18.	Pūrvāphālgunī (δ Leonis)	30
19.	Uttarāphālgunī (β Leonis)	45
20.	Hasta (δ Corvi)	30
21.	Citrā (α Virginis)	30
22.	Svāti (α Bootis)	15
23.	Viśākhā (α Libra)	45
24.	Anurādhā (δ Scorpii)	30
25.	Jyeṣṭhā (α Scorpii)	15
26.	Mūla (λ Scorpii)	30
27.	Pūrvāṣāḍhā (δ Sagittarii)	30
28.	Uttarānṣāḍhā (σ Sagittarii)	45

It can be easily computed that

$$\sum_{n=1}^{28} (ZS)_n = 819\frac{27}{67} \text{ muhūrtas,}$$

(Where n is an integral number and it denotes the serial number of a nakṣatra starting from Abhijit (α Lyrae) as the first one.)

=Length of a nakṣatra month (sidereal revolution of moon)

[∵ 67 nakṣatra months = 1 yuga (5 year cycle)

=1830 days of 30 muhūrtas each][47]

This suggests that lunar zodiacal circumference was graduated in $819\frac{27}{67}$ muhūrtas of a nakṣatra month (sidereal revolution of moon). This veiw is strengthened by the fact that the zodiacal positions of moon and sun at syzygies were also defined in terms of balance of muhūrtas of nakṣatras (asterisms) occupied by them respectively. For instance, SP. 10. 22. 15 states : (Quotation No 2.3-3).

"At the ending moments of the last 62nd pūrnimā (full moon day) of the five-year-cycle. Which nakṣatra (asterism) is occulted by moon ?

(The answer is) Uttarāṣāḍhā (σ Sagittarii); the ending moments of Uttarāṣāḍha (σ Sagittarii).

Which nakṣatra (asterism) is occulted by sun at that time ?

(The answer is) Puṣya (δ Cancri) nakṣatra (asterism) with balance of $19\frac{43}{62} + \left(\frac{1}{62} \times \frac{1}{67} \times \frac{33}{1}\right)$ muhūrtas."

These data can be easily generated. We know that on the full-moon day,

$L_s \sim L_m$ = half the zodiacal cicumference,

Where L_s and L_m denote longitudes of sun and moon respectively on a full-moon day.

$$\therefore L_s \sim L_m = \frac{1}{2} \times 819\frac{27}{67} \text{ muhūrtas}$$

$$(\because \text{ zodiacal circle } = 819\frac{27}{67} \text{ muhūrtas})$$

$$= 409\frac{47}{67} \text{ muhūrtas}$$

In the present case,

$L_m = O$, because zero of the scale of graduating the zodiacal circumference in muhūrtas coincides with the ending moments of Uttarāṣāḍhā (σ Sagittarii) or beginning of Abhijit (α Lyrae) nakṣatra (asterism) where the moon is posited at the end of sixty-second pūrṇimā (full moon day) or the beginning of the five year cycle.

$$\therefore \quad L_s = 409\frac{47}{67} \text{ muhūrtas}$$

$$= \left(429\frac{27}{67} - 19\frac{47}{67}\right) \text{ muhūrtas.}$$

=Ending moments of Puṣya (δ Cancri)—

$$\left[19\frac{43}{62} + \left(\frac{1}{62} \times \frac{1}{67} \times \frac{33}{1}\right)\right] \text{ muhūrtas}$$

(using table No. 2.3-1)

$$= 19\frac{43}{62} + \left(\frac{1}{62} \times \frac{1}{67} \times \frac{33}{1}\right) \text{ muhūrtas balance of}$$

Puṣya (δ Cancri)

Similarly the positions of moon and sun can also be generated at other syzygies. This shows that the zodiacal circumference was graduated in muhūrtas of a nakṣatra month (sidereal revolution of moon).

The time for which a nakṣatra (asterism) combines with sun can be easily computed by applying ratio and proportion as follows :

x : y : : sidereal revolution of sun : sidereal revolution of moon

where x=The period for which sun in its sidereal revolution combines with a nakṣatra

y=Zodiacal stretch of the nakṣatra (asterism) in muhūrtas or the period for which moon in one sidereal revolution combines with it.

$\because$ Sidereal revolution of sun=366 days of 30 muhūrtas each =10980 muhūrtas

and sidereal revolution of moon= $819\frac{27}{67}$ muhūrtas

$\therefore$ x : y :: 10980 : $819\frac{27}{67}$

or $x = \frac{67}{5} \gamma$ ... ... (2.3-1)

$\therefore$ If $y = 9\frac{27}{67}$ muhūrtas, x=4 days and 6 muhūrtas

y = 15 muhūrtas, x = 6 days and 21 muhūrtas

y = 30 muhūrtas, x = 13 days anb 12 muhūrtas

and y = 45 muhūrtas, x = 20 days and 3 muhūrtas

The value of x as derived above are also stated in JP. 9.8 as (Quotation No. 2.3—4)

i.e. "Abhijit (α Lyrae) combines with sun for 4 days 6 muhūrtas only. (1) Śatabhiṣa (λ Aquarii), Bharaṇi (41 Arietis), Ārdrā (α Orionis), Āśleṣā (ϵ Hydrae), Svāti (α Bootis) and Jyeṣṭhā (α Scorpii) (6 nakṣatras) combine (with sun) for 6 days and 21 muhūrtas each. (2) Three Uttarās (*viz*. Uttarābhādrapada *i.e.* γ Pegasi, Uttarāphalguni *i e.* β Leonis, and Uttarāṣaḍhā *i e.* σ Sagittarii), Punarvasu (β Geminorum), Rohini (α Tauri) Viśākhā (α Libra) (6 nakṣatras) combine (with sun) for 20 days 3 muhūrtas each. (3) The rest of the 15 nakṣatras (asterisms) combine (with sun) for 13 days 12 muhūrtas each."

This suggests that zodiacal circumference was graduated in days of a solar year. But this seems to be of theoretical interest only.

(2) Later, we find still a minute division of zodiacal circumference. The actual velocities of sun and moon are depicted with 54900 celestial parts (abbreviated, C.P.) equivalent to the 360° of the modern celestial sphere. SP. 15.2—3 states : (Quotation No. 2.3—5)

"How may parts does moon move in one muhūrta (48 minutes) ?

(Moon) moves 1768 parts of the maṇḍala (diurnal circle) on which (moon) moves, whereas the maṇḍala (diurnal circle) is divided into 109800 parts.

How many parts does sun move in one muhūrta ?

(The sun) moves 1830 parts of the maṇḍala (diurnal circle) on

which (sun) moves, whereas the maṇḍala (diurnal circle) is divided into 109800 parts."

The rationale of this expression is easily discernible.

$\because$ The two moons describe a maṇḍala (diurnal circle) of 109800 parts in one lunar sāvaṇa day (moonrise to moonrise).

$\therefore$ Velocity of either moon $= \frac{109800}{2}$ parts/lunar sāvaṇa day

$= 54900$ parts/lunar sāvaṇa day

Again,

$\because$ 1768 lunar sāvaṇa days $= 1830$ days of 30 muhūrtas each[47]

$\therefore$ 1 lunar sāvaṇa day $= \frac{1830 \times 30}{1768} = \frac{54900}{1768}$ muhūrtas

$\therefore$ Velocity of either moon $= 54900$ parts/ $\frac{54900}{1768}$ muhūrtas

$= 1768$ parts/muhūrta

Similarly,

Velocity of either Sun $= \frac{109800}{2}$ parts/day of 30 muhūrtas

$= 1830$ parts/muhūrta.

This indicates that the zodiacal circumference was graduated into 54900 celestial parts (gagana khaṇḍas).

It may be seen that this number 54900 is the same as the number of muhūrtas in a five-year-cycle, for

One five-year-cycle $= 1830$ days $= 54900$ muhūrtas

($\because$ 1 day $= 30$ muhūrtas)[10]

$\therefore$ Numerically,

54900 C.P. $= 54900$ muhūrtas in a five-year cycle.

Thus the earlier concept of dividing zodiacal circle in the ratio of muhūrtas of 28 nakṣatras (asterisms) in a nakṣatra month (sidereal revolution of moon) was further developed into dividing zodiacal circle in the ratio of respective sums of muhūrtas of 28 nakṣatras (asterisms) in a five-year cycle.

$\because$ One five-year cycle $= 67$ nakṣatra months[47] (sidereal revolutions of moon)

$\therefore$ Numerically,

54900 C.P. $= 67 \times$ length of a nakṣatra month in muhūrtas,

$$\text{or} \sum_{n=1}^{28} (\text{C.P. of nakṣatra})_n = 67 \sum_{n=1}^{28} (\text{ZS})_n$$

where n is the serial number of a nakṣatra (asterism) starting from Abhijit (α Lyrae) as the first one.

∴ C.P. of nakṣatra (astrism)=67 ZS ... (2.3.-2).

∴ From eq. No. (2.3-2), zodiacal stretch in C.P. of every nakṣatra (asterism) can be easily computed. L.C. Jain has compared the celestial parts of nakṣatras (asterisms) with modern degrees of arc. A typical table is reproduced below :

TABLE NO. 2.3-2
NAKṢATRAS (ASTERISMS) AND THEIR ZODIACAL STRETCHES IN C.P.

S. No.	Name of asterism	Stretch in C.P.	Remarks, stretch from and upto
1.	Aśvinī	2010 C.P. from O.C.P.	Aries from O onwards.
2.	Bharaṇī	1005 C.P.	Aries
3.	Kṛttikā	2010 C.P.	Aries upto 4575 and Taurus 450 C.P.
4.	Rohiṇī	3015 C.P.	Taurus
5.	Mṛgaśirṣa	2010 C.P.	Taurus upto 4575 and Gemini 900 C.P.
6.	Ārdrā	1005 C.P.	Gemini
7.	Punarvasu	3015 C.P.	Gemini 4575 and Cancer 345 C.P.
8.	Puṣya	2010 C P.	Cancer
9.	Āśleṣā	1005 C.P.	Cancer
10.	Maghā	2010 C.P.	Cancer 4575 and Leo 795 C.P.
11.	Pūrvāphālgunī	2010 C.P.	Leo
12.	Uttarāphālgunī	3015 C.P.	Leo 4575 and Virgo 1245 C.P.
13.	Hasta	2010 C P.	Virgo
14.	Citrā	2010 C.P.	Virgo 4575 and Libra 690 C.P.

1		2	3
15.	Ṣvāti	1005 C.P.	Libra
16.	Viśākhā	3015 C.P.	Libra 4575 and Scorpic 135 C.P.
17.	Anurādhā	2010 C.P.	Scorpio
18.	Jyeṣṭhā	1005 C.P.	Scorpio
19.	Mūla	2010 C.P.	Scorpic 4575 and Sagittarius 585 C.P.
20.	Pūrvāṣāḍhā	2010 C.P.	Sagittarius
21.	Uttarāṣāḍhā	3015 C P	Sagittarius 4575 and Capricorn 1035 C.P.
22.	Abhijit	630 C.P.	Capricorn
23.	Śravana	2010 C.P.	Capricorn
24.	Dhaniṣṭhā	2010 C.P.	Capricorn 4575 and Aquarius 1110 C P.
25.	Śatabhiṣā	1005 C.P.	Aquarius
26.	Pūrvābhādrapada	2015 C P.	Aquarius
27.	Uttarābhādrapada	3015 C P	Aquarius 4575 and Pisces 2565 C.P.
28.	Revatī	2010 C.P.	Pisces 4575 and Aries O.C P.

Incidentally it may be seen that the motion of sun (1830 C.P. per muhūrta) relative to that of moon (1768 C.P. per muhūrta) is (1830-1768=) 62 C.P. per muhurta. Thus there is a conjunction of sun and moon after $\frac{549000}{62}$ muhūrtas or 29.516 days[46] whereas the modern value is 29.5305 days [46]

(3) A new mode of graduating the zodiacal circumference is also found implied in the notion of Sīmāviṣkambha, literally 'lock of the limits' or the demarcation of the limits. The Sīmāviskambhas of the nakṣatras (asterisms) have been stated in SP.10.22-5 as : (Quotation No. 2.3-6)

i e. "Out of these 56 nakṣatras (asterisms),

(*i*) There are two Abhijits (α Lyrae) nakṣatras of $\frac{630}{30\times 67}$ Sīmāviṣkambha each.

(*ii*) There are 12 nakṣatras of $\frac{1005}{30\times 67}$ Sīmāviṣkambha each

viz. 2 Śatabhiṣās (λ Aquarii) ... ... upto 2 Jyeṣṭhās (α Scropii).

(*iii*) There are 30 nakṣatras of $\frac{2010}{30\times67}$ Sīmāviṣkambha each, viz. 2 Śravaṇas (α Aquilae) ..... upto 2 pūrvāṣāḍhās (δ Sagittarii).

(*iv*) There are 12 nakṣatras of $\frac{3015}{30\times67}$ Sīmāviṣkambha each, viz. 2 Uttārabhādrapadas (γ Pegasi) ... ... upto (two) Uttārāṣadhās (σ Sagittarii)."

It is evident by inspection that Sīmāviṣkambha of any nakṣatra (asterism) is $\frac{630}{30\times67}$, $\frac{1005}{30\times67}$, $\frac{2010}{30\times67}$ or $\frac{3015}{30\times67}$ corresponding to its zodiacal stretch in mūhurtas, *i.e.* $9\frac{27}{67}$, 15, 30 or 45 muhūrtas respectively (see table No. 2.3-1). If the zodiacal stretches in muhūrtas are converted into zodiacal stretches in days of 30 muhūrtas each, we have,

$$\text{Zodiacal stretch in days} = \frac{\text{Zodiacal strech in muhūrtas}}{30} \quad (2\ 3\text{-}3).$$

Using this relation, ZS in days of any nakṣatra may be easily computed. Thus the following table of nakṣatras and their zodiacal stretches in days may be easily got.

TABLE NO. 2.3.3.

NAKṢATRAS AND THEIR ZODIACAL STRETCHES (=ZS) IN DAYS

Total number of nakṣatras (asterisms)	*ZS in muhūrtas*	*ZS in days*	*ZS in days with the same denominator 30×67*
1	$9\frac{27}{67}$	$\frac{630}{30\times67}$	$\frac{630}{30\times67}$
6	15	$\frac{15}{30}$	$\frac{15}{30}\times\frac{67}{67}=\frac{1005}{30\times67}$
15	30	$\frac{30}{30}$	$\frac{30}{30}\times\frac{67}{67}=\frac{2010}{30\times67}$
6	45	$\frac{45}{30}$	$\frac{45}{30}\times\frac{67}{67}=\frac{3015}{30\times67}$

In the light of foregoing discussion this shows that Sīmaviṣkambhas of nakṣatras (asterisms) represent their zadiacal stretches in days expressed as fractions having the same denominator probably for a better comparison. Thus the zodiacal circumference was graduated in days of a nakṣatra month *i e* $\frac{54900}{30\times 67}$ days. The correspondence between days of nakṣatras and the modern degrees of arc work out as follows :

$$\frac{54900}{60\times 67} \text{ days (time degrees)} = 360^\circ$$

$$\frac{630}{30\times 67} \text{ days} = 4\frac{8^\circ}{61}$$

$$\frac{1005}{30\times 67} \text{ days} = 6\frac{36^\circ}{61}$$

$$\frac{2010}{30\times 67} \text{ days} = 13\frac{11^\circ}{61}$$

$$\frac{3015}{30\times 67} \text{ days} = 19\frac{47^\circ}{61}$$

(4) Later still a grand scheme of graduating the zodiacal circumference was evolved. This is based on the fact that 360 saura days (saura day equals the time taken by sun to move on 1/360th part of zodiacal circle) make 3 seasons of 4 saura months (a saura month consists of 30 saura days) each. In this context JP. 9.17-19 states (Quotation No. 4.3-1).

(1) "How many nakṣatras (asterisms) are completed in the first month of Varṣā (rainy season) ?

(The answer is) Uttarāṣāḍhā (σ sagittarii) remains for 14 āhorātras (days and nights), Abhijit (α Lyrae) for 7 ahorātras, and Dhaniṣṭhā (β Delphini) for one ahorātra.

Second month of Varṣā...Dhaniṣṭhā (β Delphini) for 14 ahorātras (days and nights), Śatabhiṣā (λ Aquarii) for 7 ahorātras, Pūrābhādrapada (α Pegasi) for 8 ahorātras, and Uttarābhādrapada (γ Pegasi) for one ahorātra.

Third month of Varṣā...Uttarābhādrapada (γ Pegasi) for 14 ahorātras, Revatī (ξ Piscium) for 15 (ahorātras) and Aśvinī (β Arietis) for one (ahorātra).

Forth month of Varṣā...Aśvinī (β Arietis) 14 Bharṇī (41 Arietis) 15 and Kṛttikā (η Tauri) for one (ahorātra).

(2) First month of Hemanta (Winter)..Krittikā (η Tauri) 14, Rohinī (α Tauri) 15 and Mṛgaśīrṣa (λ Orionis) for one ahorātra (day and night).

Second month of Hemanta ... Mṛgaśirṣa (λ Orionis) for 14, Ārdrā (α Orionis) 8, Punarvasu (β Geminorum) 7 and Puṣya (δ Cancri) for one ahorātra

Third month of Hemanta...Puṣya (δ Cancri) for 14 ahoratras, Āśleṣā (ε Hydrae) 15 and Maghā (α Lenois) for ahorātra.

Fourth month of Hemanta ... Magha (α Leonis) for 14 ahorātras. Pūrvāphālgunī (δ Leonis) 15 ahorātras and Uttarāphālgunī (β Leonis) for one ahorātra.

(3) First month of Grīṣama (Summer) ... Uttarāphālgunī (β Leonis) for 14 ahorātras. Hasta (δ Corvi) 15 ahorātras and Citra (α Virginis) for one ahorātra.

Second month of Grīṣama ... Citra (α Virginis) for 14 ahorātras. Svāti (α Bootis) for 15 ahorātras, Viśakhā (α Libra) for one ahorātra.

Third month of Grīsama ... Viśakha (α Libra) for 14 ahorātras Anurādha (δ Scorpii) for 8 ahorātras, Jyeṣṭhā (α Scorpii) for 7 ahorātras and Mūla (λ Scorpii) for one ahorātra.

Forth month of Grīṣama ... Mūla λ Scorpii) for 14 ahorātras, Pūrvāṣāḍhā (δ Sagittarii) for 15 ahorātras, Uttarāsāḍhā (σ Sagittarii) for one ahorātra."

These data may be seen at a glance in Table No (4.3-1).

This shows that 20 individual nakṣatras (asterisms) plus 4 pairs of nakṣatras (asterisms) *i e* Abhijit (α Lyrae) and Śravaṇa (α Aquilae), Śatabhiṣā (λ Aquarii) and Pūrvābhādrapada (α Pegasi), Ārdrā (α Orionis) and Punarvasu (β Geminorum), and Anurādhā (δ Scorpii) and Jyeṣṭhā (α Scorpii) have been allocated 15 saura days each. This hints upon a 24 fold division of zodiacal circumference comprised of 360 saura days (saura day equals the time taken by sun to move on 1/360th part of zodiacal circle).

Besides, we find that Uttarāṣāḍhā (σSagittarii) lying near Winter solstice is associated with last saura day of the fourth saura

month of Grīṣama (Summer) when the sun is in the neighbourhood of Summer solstice. This shows that the number of saura days associated with any nakṣatra (asterism) represents its number of acronical *risings in* the eastern horizon after sunset. In this context, Henry C. King[54] also refers to the use of dekanal system, a kind of clock calendar of the stars, constellations and parts of constellations based on a year of 360 days, used by priests in some parts of the east. With the observed disposition of dekan stars, both the time and the direction could be found out. Ipso facto the Jainian approach may be contemplated as a sign of graduating the zodiacal circumference into 360 saura days.

Besides, If Summer ends with sun at Summer solstice, Winter solstice coincides with one saura day of Uttarāṣāḍhā (σ Sagittarii) *i.e.* fourteen saura days (time degrees) preceding Winter solstice coincided with Abhijit (α Lyrae) nakṣatra (see table No. 4.3-1). Taking seventy-two years for 1° (=one saura day) of precession, we have,

14° (saura days) of precession $= 72 \times 14 = 1008$ years.

Thus this observation dates about 1008 years after Winter solstice coincided with the begining of Abhijit (α Lyrae) nakṣatra. So the event might have occurred in about seventh-eighth century A.D.

(a) *Discussion*

In Vedic period, days were called after the name of nakṣatras (asterisms).[48]. That was the first attempt to graduate zodiacal circumference in 27 days of a lunar sidereal revolution. Moon travels by definition through twenty-seven nakṣtras (asterisms) in each sidereal revolution.[49] Pingree[66] points out from the Rk. recension, verse 18, that twenty-seven nakṣatras (asterisms) have been interpretted as equal arcs of $13^\circ\ 20'$ each. It is, of course, true that from verse 18 of the Rk. recension, we find that moon travels through a nakṣatra (asterism) in one day and seven kalās such that it completes sixty-seven lunar cycles or covers $1809 (= 67 \times 27)$ nakṣatras (asterisms) in a five-year cycle of 1830 days. But this is the average motion of moon. An estimate of mean position of moon could be easily made on this basis and the position of moon in the neighbourhood of any bright star could help determine the the name of day. In this way the conjunction stars of nakṣatras (asterisms) must have been identified. Distance between conunction

stars of any consecutive nakṣatras is not constant. So a nakṣatra cannot be easily corresponded to an arc of 13° 20′. Similarly Biot guessed that Hindu nakṣatras (asterisms) were theoretically generated corresponding to 27 days for which moon remains visible in a lunar month.[50] In the light of this discussion, Biot's views are easily refutable. The ancient Hindus were aware of lunar stations among the stars. A remarkable advancement in this regard was made by Jaina astronomers who measured the longitudinal stretches of nakṣatras (asterisms) in days of a nakṣatra month (sidereal revolution of moon). A naked eye observer rounded off the zodiacal stretches of nakṣatras (asterisms) to the nearest whole number of half-days. Fifteen nakṣatras (asterisms) obtained two half-days each, six nakṣatras one half-day each and naturally the rest of the six nakṣatras three half-days each so as to correspond the twenty-seven nakṣatras (asterisms) with twenty-seven days. But the length of a nakṣatra month (sidereal revolution of moon is $9\frac{27}{67}$ muhūrtas or $\frac{21}{67}$ days ($\because$ 30 muhūrtas = 1 day) more than twenty-seven days. Thus the inclusion of Abhijit (α Lyrae) nakṣatra (asterism) with zodiacal stretch $9\frac{27}{67}$ muhūrtas or $\frac{630}{30 \times 67}$ days was necessitated. Kaye mentions that Abhijit (α Lyrae) is the extra nakṣatra (asterism) and there is a legend (Maitraiya Brāhmaṇa iii 230.11) that it dropped out, but Taittirīya Brāhamaṇa (1.5.2.3) marks it as a new comer.[51] This fact hints that Jaina system of astronomical thought had established its identity in the Brāhmaṇic period also and zodiacal circumference was graduated in twenty-eight nakṣatras (asterisms) corresponding to $27\frac{21}{67}$ days of a nakṣatra month (sidereal revolution of moon). It is worthy of note that $27\frac{21}{67}$ or 27.313 days is the length of a nakṣatra month (sidereal revolution of moon) correct upto one place of decimal fraction. (The correct value is 27.3216615 days).[52] Thus the arguments of Sir W. Jones et al[53] that perfect exactness being either not attained or not required by Hindus, they fixed on the number twenty-seven and inserted Abhijit (α Lyrae) for some astrological purpose for their nuptial ceremonies, are altogether questionable Zodiacal stretch of a nakṣatra (asterism) in days was called its Sīmāviṣkambha.

Later on Simāviṣkambhas of all the nakṣatras (asterisms) were converted into muhūrtas and thus the zodiacal circumference was graduated in $819\frac{27}{67}$ muhūrtas of a nakṣatra month (sidereal revolution of moon). Then still a minute division was evolved. A muhūrta (time degrees) was sub-divided into sixty-seven parts known as celestial parts (gagana khaṇḍas) such that the zodiacal circumference was graduated into 54900 C.P.

About a thousand year after Winter solstice coincided with the beginning of Abhijit (α Lyrae) nakṣatra (asterism) i.e. in near about third-fourth century A.D. they Switched from the lunar motion over to the solar motion and divided the zodiacal circle into twenty-four equal parts, each part representing a nakṣatra (asterism) except four parts which represented a pair of nakṣatras (asterisms) each. The zodiacal circumference was clearly graduated in 360 saura days of a saura year. (In ancient Chinese astronomy, too, zodiacal circumference was graduated in number of days in a year.[28] This led to the division of zodiacal circle in 360^0 and the equal amplitude system of nakṣatras (asterisms) was developed when Abhijit (α Lyrae) was again dropped with the advent of Siddhāntic astronomy The use of twenty-seven nakṣatras (asterisms) only is also hinted upon in Samavāyāṅga Sūtra (=SVS).

SVS, 27 2 states : (Quotation No. 2.3-7).

"Leaving aside Abhijit (α Lyrae), only twenty-seven nakṣatras (asterisms) are used in Jambūdvipa (isle of Jambū tree)."

The role of Jaina School of astronomy in allocating the number of muhūrtras to nakṣatras (asterisms) has left an everlasting impact on Indian astrological thought so much so that every Saṅkranti (solar ingress) etc. is termed as 15, 30 or 45 muhurti (pertaining to muhūrtas) corresponding to the zodiacal stretch in muhurtas of the nakṣatra (astrism) occupied by sun at that time.[62] No such series of developments is found in any Babylonian tablets of remote antiquity. Zodiac as known to Babylonians appears however for the first time in texts of the year 419 B.C.[63] The series of developments of graduating the zodiacal circumference suggests the Hindu Origin of its division into modern degrees.

It may be worth mentioning here that the solar division of zodiac in India is the same in substance as that used in Greece. Sir W. Jones[61] remarks that both Greeks and Hindus owe it to an older nation who first gave names to the luminaries of heaven. Need it be emphasized that the hitherto unexplored Jaina contribution in the history of division of zodiacal circle is unique in character of its Hindu origination.

CHAPTER III

Jaina Cosmography

This chapter deals with Jaina tentative astronomical model of cosmos. It is however worthy of note that any such model is never an exact image of the real world. Some presumptions are somehow indispensable. Also there may be some drawbacks in thinking. Sometimes the best models available may yield results which differ by more than 100 per cent from the results of actual physical measurements,[33] *e.g*, some models in nuclear physics etc. What seems to be most plausible to modern theorists like even nuclear physicists etc. may be totally discarded after a few years of development Likewise Jainas had devised a tentative astronomical model of cosmos and its utility lay in explaining certain astronomical phenomena to some extent. Application of their principle of syādvāda[35] (theory of relative probability) renders it more understandable. However in order to discern properly the implications of Jaina tentative astronomical model of cosmos, one must develop a framework of mind similar to that of Jaina scholars of ancient times The essence manifest in this thought lies in the words of John Taylor[36] which are apt to be reproduced here as :

> "Are we not limited in what we see around us by our ways of thought; if we had different brains could we not somehow have a different logic and see a very different universe."

Besides, Semantic changes also do play a great role in arousin confusion. For example, Jaina notion that moon goes 80 Yojanas higher than sun looks apprently very strange and scholars like Shankar Balkrishan Dixit[10] tried to explain it to be the vertical height. In fact the word 'height' implied a notion of celestial latitude [11] As moon's orbit is inclined to that of sun, the relevant statement refers to this very situation which is quite confusing

in modern astronomical concepts of vertical distances of heavenly bodies.

Now let us make a simple probe into the theory of peculiar notions most popular among exponents of Jaina School of astronomy.

3.1 NOTION ABOUT SHAPE OF EARTH

Man had been continuously striving for a formulation of concepts which will permit description of the real world in mathematical terms. Consequently there was no dearth of any wonderous types of cosmological and cosmographical notions among all ancient nations. Ancient Greek intellectuals had developed certain peculiar notions. The earth was supposed to be cake-shaped by Anaximander (611-546 B.C.) and to be surrounded by a sphere of air outside which there was a sphere of fire. Pythagoreans supposed the universe to consist of separate concentric spheres of crystal which respectively carried along by their rotation moon, sun, each of five planets and the whole body of fixed stars; and these spheres in their rapid motion emitted a music to be perceived only by those of the most exalted faculties. Anaxagoras (c. 500-428 B C.) of Klazomenae believed that sun was a mass of blazing metal as big as Greece and the other heavenly bodies are alike masses of rock. It is also said that Anaximander (611-546 B.C.) of Miletus had suggested about 550 B.C. that men lived on the surface of a cylinder that was curved north and south [2] Egyptians[3] belived that earth was rectangular like their country.

The cosmic viewpoints most popular among Japanese intellectuals at the beginning of Tokugawa regime (sixteenth century A.D.) were the Confucian Ten'en-Chiho-ron i.e. the theory that heaven is round and earth is square. This theory was upheld by Japanse people even upto the middle of seventeenth century A.D.[4] According to Chinese[5] cosmic viewpoints, earth is square and heaven is like a hen's egg and earth in it like the yolk.

Besides, we may have a peep into the notion of counter bodies. Chines had imagined from ancient times, the existence of a 'counter jupiter' which moved round. diametrically opposite to the planet itself; Greeks had also a parallel to this in the strange Pythagorian theory of the 'counter-earth' apparently due to Philolaus of

Tarentum (480-? B C.), which was devised either to bring the number of planets upto a perfect number ten or to explain lunar eclipses.[8]

Similar notions were also prevalent among vedic people. According to Rigveda (X 89), earth was regarded circular like a wheel and also according to some other verses of Rigveda (III,55), earth has the shape of a bowl and also the heaven has an alike one, the two great bowls being face to face with each other.[6] Likewise Jainas had also a different cosmological scheme and believed that earth was made up of a series of flat concentric rings of land masses alternatively surrounded by concentric ocean rings. The central island of earth was called Jambūdvīpa i.e. isle of the Jambū-tree, and the mount Meru was placed at its centre.[7] The notion of flat earth was closely related with their peculier theory of two suns, two moons and two sets of nakṣatras (asterisms) which were assumed to move in circles parallel to earth's surface round the Mount Meru.

Apparently these theories seem to be very strange. For reasons elucidated before they should not be prima facie discarded. Let us have a probe into the theory of cosmic viewpoints most popular among exponents of Jaina School of Astronomy.

Jainas might have perceived that mandalas (dirunal circles) of sun are almost concentric Consequently Jaina perceived the mount Meru placed at the common centre of these circles such that two suns, two moons etc moved in their diurnal circles round the mount Meru Concept of Meru has been dealt with in detail in the subsequent section (see 3.2) and there it is shown that the celestial angular distances were measured with the aid of gnomon in corresponding distances projected over the surface of earth.[14] The increasing diameters of maṇḍalas ('diurnal circles' projected over the surface of earth) of sun on its southern journey and vice versa were measured along the surface of earth ; 65 solar maṇḍalas (sun's diurnal circles) are stretched over 180 Yojanas (measured actually) in Jambūdvīpa (isle of Jambū tree) and 119 solar maṇḍalas over 330 Yojanas (manipulated theoretically) in lavaṇasamudra (salt ocean) (for details, see 5.1). Probably because of strong impact of circularity of solar maṇḍalas ('sun's diurnal circles' pro-

jected over the surface of earth), Jainas might have been led to conceive that they lived on a circular land mass surrounded by lavaṇasamudra (salt ocean). Probably because of unawareness of finiteness of earth, Jainas had further envisaged as if the earth was made up of circular land masses alternatively surrounded by ocean rings. In the absence of knowledge of roundity of earth, Jainas might have been tempted to propound their notion of flatness of earth to fit their theory of circular land masses alternatively surrounded by ocean rings. It may be remarked here that we have expounded simply the probable course of such developments but compared Greek and other peoples' notions about shape of earth, Jainian notion of circular and flat earth seems quite peculiar to exponents of Jaina School of astronomy.

Aristotle (384-322 B.C.) put forward the idea that earth was not flat.[36] But the Greek philosopher, Philolaus of Tarenturm (480-? B.C.) is also said to have first suggested about 450 B.C. that earth was a sphere[15] Such a notion is not at all found in Jaina canonical literature whose present recension is traditionally ascribed to the council of valabhī which met during the reign of Dharuvasena I (ca. A.D. 519-549) (see 2.1). However the old recensions of Jaina canonical works might have been in vogue quite early in the pre-Christian era, at least before the Greek contact

It is worth, of note that because of notion of flatness of earth, Jainas could not solve the mystery of theory of two suns and two moons etc. Jambūdvīpa (isle of Jambū tree) is divided into four directions. As sun should make the day in succession of the regions south, west, north and east of Meru. sun's diurnal orbit is also divided into four quarters; the same sun making day over Bhāratavarṣa in the southern quarter cannot reappear on the following morning as it still has three quarters to travel. To obviate this difficulty. the theory supposes two suns, Bhārata and Airāvata, separated from each other by half the orbit, to describe the whole orbit.[7] This theory is quite confusing these days but it certainly depicts peculiar thinking of Jaina scholars. L.C. Jain opines that the mystery of the real and counter bodies existent in the Jaina Parkrit texts, China and Greece has not yet been unearthed, although it has been a theory for certain calculations.[8] In the light of foregoing discussion it may be contemplated that

Jainas might have not necessarily belived in the actual existence of two suns, etc. For mathematical calculations, only one sun. one moon and one set of nakṣatras suffice. But this theory had served purposes like those of tentative astronomical model of cosmos. This theory fairly worked over many centuries together for solving the practical problems Jainas encountered in formulizing the description of real world around.

Besides, it is also said that Aristarchus of Samos (about 310-230 B C.) put forward the hypothesis that the earth revolves round the sun but Ptolemy clung to the geocentric theory which remained standard throughout the middle ages[36] Like all other ancient people of the world Jainas also believed in the geocentric theory. All Jyotiṣikas (astral bodies, viz. sun, moon, grahas or planets, nakṣatras or asterisms, and tārās or stars) move about the earth.

However, still new horizons in the development of cosmological models are cropping up and new theories are being tested by the cosmologists without reaching any ultimate conclusion.[37] Different brains have always a different logic and see a very different universe.

3.2 *NOTION OF OBLIQUITY OF ECLIED IN THE CONCEPT OF MOUNT MERU*

Here a simple probe is rendered into the concept of mount Meru and it is revealed that dimensions of Muru Fit certain astronomical constants, e. g. obliquity of ecliptic. Thus Meru represents a tentative astronomical model of notion of obliquity of ecliptic. This model plays an important role in unearthing the meaningful concepts of Jainian notions like those of flat earth and samatala bhūmi ('earth having plane surface' denoting on earth a circular area with centre at the projection of pole of ecliptic) etc.

(a) *A Historical View of Location of the Mount Meru*

There are sixteen name-variants of Meru viz.[38]

1. Mandara
2. Girīrāja
3. Meru
4. Priyadarśana
5. Ratnoccaya
6. Lokanābhi
7. Manorama
8. Sudarśana
9. Diśādi
10. Uttama
11. Asta (accha)
12. Sūryavarta
13. Svayamprabha
14. Vatanka
15. Lokamadhya
16. Sūryavaraṇa.

As regards astronomical significance of these names, only a few of them are meaningful, e.g. Lokanābhi (naval of the world or a division of universe). Diśādi (meaning like something from which directions are indicated). and Lokamadhya (centre of the world). Other names are, more or less, literary types, e g. Priyadarśana (beautiful), uttama (best), Girīrāja (king of mountains) etc.

There are many different theories about location of the mount Meru.[16] Parāśara opines that Meru stands in the heart of Jambūdvīpa (isle of Jambū tree). A second theory is that Meru consists of highlands of Tartary immediately north of the Himalayas, meaning no doubt the plateaux of Tibet and Pāmīra [17] Bhāskarācārya considered Meru as the abode of the gods—Brahmā, Viṣṇu and Śiva This is why the god Śiva is also called as Merudhāman and Kailāsanātha, that is, 'The god whose abode is Meru' and 'Lord of the mountain called Kailāsa' respectively.[17] Tilak[18] expresses his opinion that Meru is the terrestrial north pole of the Hindu astronomers. In support of his view he quotes a line from Sūrya Siddhānta[12] (xii.67) which means "At Meru the gods behold sun, after but a single rising, during the half of his revolution beginning with Aries" Brahmagupta[19] also says that the day of angels who inhabit Meru lasts six months, and their night also six months. Bhāskarācārya[20] also holds a similar view about the day of inhabitants of Meru.

Regarding the Hindu concept of Meru, Alberūnī[22] pointed out that it was similar to that of Zoroastrians who placed at centre of the world the mountain of Girnagar, the Taera of Avesta. Some others also say that notion of the mount Meru is possibly ascribed to a foreign origin, (ed. J.H. Woods, p. 254f).[19] The name variants Meru, Sineru and Sumeru also seem to indicate a foreign origin.[21]

The geographical scheme generally accompanying the description of Meru may be connected with the Avestan scheme of seven districts and mount Meru recalls to us the Olympus of Greeks.[19]

However, despite the diversity of opinions about the origination of concept of the mount Meru, it seems plausible that the concept of Meru rendered a vehement role in Jaina cosmography and Jaina astronomical notions were strictly interwoven with it. Jainas had perhaps for some mysterious calculations a strange theory of two suns, two moons, two sets of nakṣatras (asterisms) and

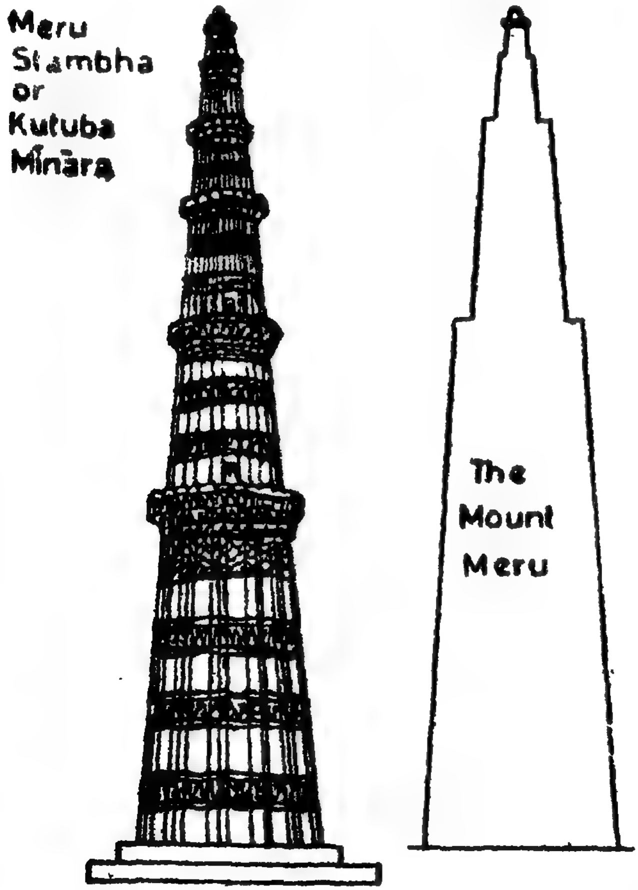


Fig No. 2·1. *Similar between the size and shape of Meru-Stambha or Kutuba Mināra in Delhi and the mount Meru.*

two sets of stars which were assumed to move in circles round the mount Meru placed at centre of Jambūdvīpa, the central island of flat earth made up of concentric rings of land masses alternatively surrounded by ocean rings (see 3.1). Evidently such a Meru seems to possess some polar characteristics.

Besides, it is worth mentioning here that Kedar Nath Prabhakar[39] stresses upon his opinion that Kutubamīnāra (Arabic synonym of the mount Meru) in Delhi had been constructed on the pattern of Meru such that 1000 yojanas were equal to one yard (see fig. No. 3.2-1) It is worthy of note that the dimensions of Kutubamīnāra in Delhi might have been chosen such as above but still more investigations are to be made in this direction. We will come to this point later in these discussions.

(b) *Dimensions of the Mount Meru*

Generally there is unanimity among scholars in attributing to Meru a fabulous size and height.[17] However, Āryabhaṭa[41] (Āryabhaṭīyam 4.11) has mentioned the diameter of Meru, giving it as one yojana. Purāṇas, however, make it 80,000 or 86,000 yojanas high etc.[22] A descriptive record of dimensions of the mount Meru is found in Jambūdvipa Prajñapti (=JP), fifth upāṅga (sub-limb) of Jaina canon. J P. IV.113 states : (Quotation No. 3.2-1).

i.e. "(Meru) is 99000 yojanas high. 1000 yojanas deep and has a diameter of $10090\frac{10}{11}$ yojanas at its base (inside the flat earth), 10,000 yojanas at the base on flat earth and 1000 yojanas at the top."

According to Tiloya Paṇṇatti[23] (gāthā 4. 1780 et seq), Meru is made up of frustrum of cones. The diameter at its lowest base is $10090\frac{10}{11}$ yojanas and it goes on decreasing uniformly upto 1000 yojanas at a height of 10000 yojanas. The decrease in diameter with regard to increase in the height above the lowest base of Meru is shown in Fig. No. 3.2-2 (a). Fig. No. 3.2-2 (b) represents the plan of Meru.

It may easily be seen that hypotenuse is always inclined at an angle θ to the vertical.

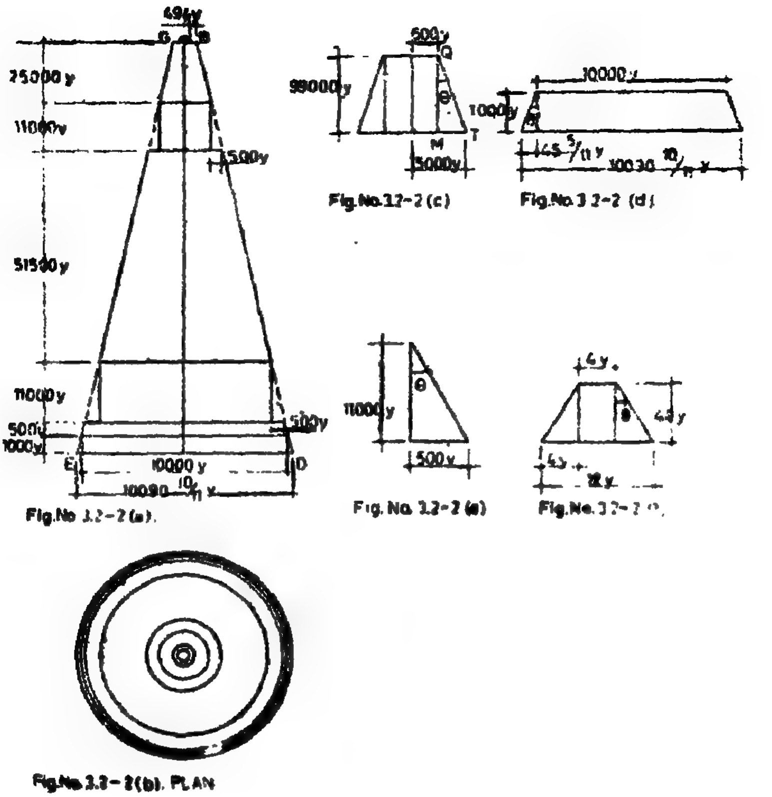


Fig. No. .2-2. *Dimensions of the mount Meru GEDB.*

Angle θ is given as

$$\tan\theta = \frac{MT}{QM} = \frac{4500}{99000} = \frac{500}{11000} \text{(see Fig. No. 3.2-2 (c)}$$

$$\tan\theta = \frac{45\frac{6}{11}}{1000} = \frac{500}{11000} \text{ see Fig. No. 3.2-2 (d)}$$

$$\tan\theta = \frac{500}{11000} \qquad \text{(see Fig. No 3.2-2 (e)}$$

Besides, at centre of the top of Meru, a cūlikā (apex or summit) having twelve yojanas diameter at its base, four yojanas diameter at its top and forty yojanas height, is situated. Hypotenuse of cūlikā (apex or summit) makes an angle θ' with the vertical

Angle θ' is given at

$$\tan \theta' = \frac{4}{40} = \frac{1}{10}$$ (see Fig. No. 3.2-2 (f)

Evidently $\theta' \neq \theta$

Thus construction of cūlikā (apex or summit) violates consistency of other dimensions of the mount Meru. The secret of this mystery is yet to be unearthed. However, the approximate from of Meru can be represented as GEBD (see Fig. No. 3.2-3).

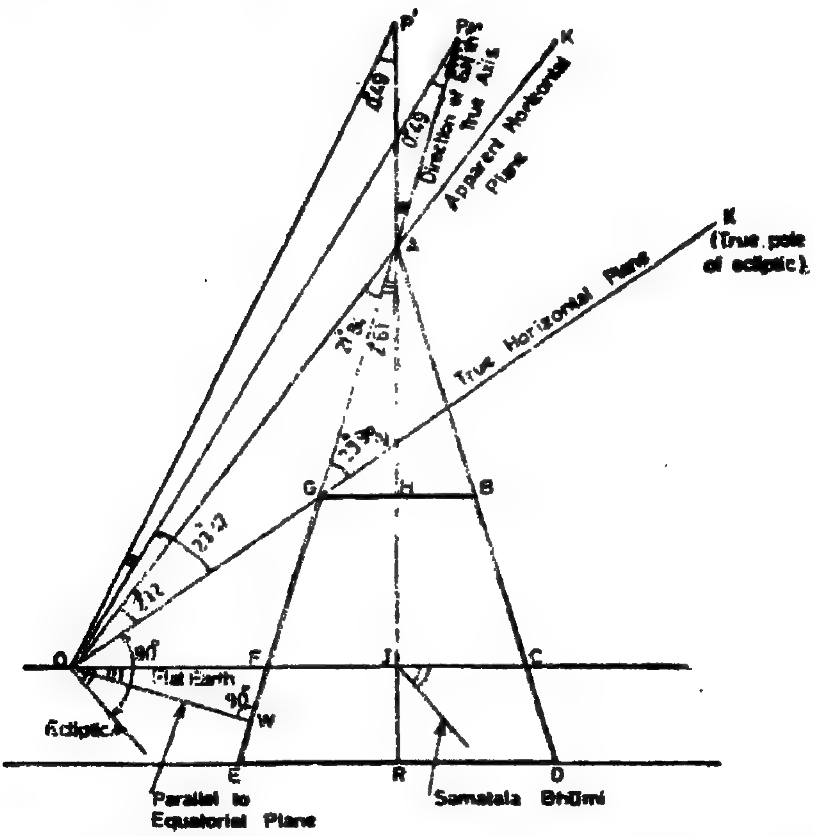


Fig. No. 2-3 *The approximate form of the mount Meru GEDB (see fig. no. 3 2-2.)* (Not to scale)

(c) ***Astronomical Model of the Mount Meru***

Now let us make a simple probe into the concept of Meru from an astronomical point of view.

In fig. No. 3.2-3), let OFJC be the plane of flat earth and FC denote the diameter of Meru on it. Let ED and GB denote the diameters of Meru at its lowest base depressed inside the flat earth and at its top respectively. RJH represents the axis of Meru. Join E, F, G and D, C, B respectively and extend them till they meet at A on the extended axis of Meru.

Now since we are given that

GB = Diameter of Meru at its top = 1000 y,
where y = ātma yojana (ADS units)

FC = Diameter of Meru on flat earth = 10000 y,

ED = Diameter of Meru at its lowest base depressed inside the flat earth

$= 10090\frac{10}{11}$ y,

HJ = Height of Meru above the flat earth = 99000 y, and

JR = Depth of Meru inside the flat earth = 1000 y.

Now in $\triangle$ AFC, $\because$ GB $\parallel$ FC,

$$\therefore \frac{AJ}{AH} = \frac{FC}{GB}$$

$$\text{or } \frac{AH+99000}{AH} = \frac{10000}{1000} \qquad (\because AJ = AH + HJ)$$

or AH = 11000 y ... ... (3.2-1)

Similarly in $\triangle$ AED, $\because$ GB $\parallel$ ED.

$$\therefore \frac{AR}{AH} = \frac{ED}{GB}$$

$$\text{or } \frac{111000}{11000} = \frac{ED}{1000} \quad (\because AR = AH + HJ + JR$$

$$= 11000 + 99000 + 1000$$

$$= 111000 \text{ y})$$

$$\text{or} \qquad ED = 10090\frac{10}{11} \text{ y}$$

= The same as given (see quot. No. 3.2-1).

This suggests that ED might have been theoretically generated

through simple geometry as above, otherwise there seems to be no logic in taking this odd value ($10090\frac{10}{11}$ y) of ED. However it is portended against any hasty conclusions about the knowledge of Geometrical Proposition methods. It is desirable to make more investigations into this field. But it is convincing that dimensions of Meru except those of its cūlikā (apex or summit), form a consistent picture. AED represents the approximate cone of Meru. The traditional mount Meru GEDB is represented by the frustrum of cones.

Now let us assume

(*i*) that the observer is situated at O lying at circumference of Jambūdvīpa (isle of Jambū tree) whose radius[24] is 50000 y.

(*ii*) that OGK represents the true horizontal plane of observer and it meets the direction of earth's axis at G such that P lies at the true celestial north pole and OW represents a plane parallel to the equatorial plane.

(*iii*) that OAK′ represents the apparent horizontal plane of observer.

(*iv*) that P′ is chosen such that its apparent altitude $\angle P'OK'$ is equal to $\angle PGK$ (the angle of inclination of axis of earth to the true horizontal plane OGK of observer.)

Now join P′ with A, the point of intersection of the apparent horizontal plane with axis of earth. Extend P′A till it meets perpendicularly the plane OFJC at J. The plane OFJC is inclined to the equatorial plane at $\angle FOW$ which is equal to $\angle FAJ$, for the angle between two planes is equal to the angle between their perpendiculars. The imaginary locus of revolution of P round P′ is projected on flat earth as the locus of F revolving round J. This produces the cone AFC. This cone is cut at G by a plane GHB parallel to flat earth. The true horizontal plane OGK meets the axis to Meru at N.

Now because earth is regarded as made up of concentric rings of land masses alternatively surrounded by ocean rings with the mount Meru placed at centre of the central island Jambūdvīpa (isle of Jambū tree), so OJ forms the radius of Jambūdvīpa.

$\therefore$ Radius of Jambūdvipa,[24] $OJ=50000y$

Now in Δ NOJ, $\quad \because GH \parallel OJ$,

$$\therefore \frac{NH}{NJ}=\frac{GH}{DJ}$$

or $$\frac{NH}{NH+99000}=\frac{500}{50000} \quad (\because GH=\tfrac{1}{2}GH, \text{ and } NJ=NH+HJ)$$

$\therefore NH=1000$ y

Also we have

$JR=1000$ y (given)

It suggests that height NH is preserved in terms of JR (depression of Meru inside the flat earth) and the diameter ED was theoretically generated as shown before.

Now the various angles are computed as below :

$$\angle OAJ=\tan^{-1}\frac{OJ}{AJ}=\tan^{-1}\frac{50000}{110000}=24^{\circ}.45$$

$$\angle FAJ=\tan^{-1}\frac{FJ}{AB}=\tan^{-1}\frac{5000}{110\ 00}=2^{\circ}.61$$

$$\angle AOJ=\tan^{-1}\frac{AJ}{OJ}=\tan^{-1}\frac{110000}{50000}=65^{\circ}.55$$

$$\angle NOJ=\tan^{-1}\frac{NJ}{OJ}=\tan^{-1}\frac{100000}{50000}=63^{\circ}.43$$

and

$\because \angle ACG=\angle AOJ-\angle NOJ=2^{\circ}.12$

$\angle OAF=\angle OAJ-\angle FAJ=21^{\circ}.84$

$\therefore \angle PGK=\angle OAF+\angle ACG=23^{\circ}.96$

By assumption *iv*, we have

$\angle P'OK'=23^{\circ}.96$,

and $\angle P'AK'=\angle OAJ=24^{\circ}.45$

$\therefore \angle P'=\angle P'AK'-\angle P'OK'=0^{\circ}.49$

Since P' and P are very far off from O and they are close to each other, $\angle P$ is almost equal to $\angle P'$ for all practical purposes,

i.e. $\angle P = 0°.49$

$\therefore \angle POK = \angle PGK - \angle P = 23°.47$

$= 23°.5$ approx.

i.e. The true altitude of the celestial north pole is 23°.5.

Since altitude of celestial north pole is equal to the terrestrial latitude of observer,

$\therefore$ Latitude of observer (in India) situated at O,

perhaps Ujjain (23°.90 N) or Patna (25°.37 N)

$= 23°.5$..................(3.2-2)

Evidently, this result better suits Ujjain, a renowned seat of ancient Indian Culture.

Besides it may be noted that according to this exposition, sun's maximum declination (obliquity of ecliptic) comes out to be 23°.96 ($\angle PGK$) whereas observer's terrestrial latitude with sun overhead on summer solstice day comes out to be 23°.47 ($\angle POK$). Since terrestrial latitude is less than astronomical latitude, and taking into account error due to actual shape of earth etc. it may be contemplated that these results form a consistent picture within limits of error due to naked eye observation.

On the other hand, we also have

$\because$ F lies at north extremity of earth's axis (projection of celestial north pole P on earth),

$\therefore$ Terrestrial co-latitude of the observer $= OF$

$= OJ - FJ$

$= 45000$ y

$= 720$ Y

where Y = Yojana (TP Units)[25],

and -1 y $= \frac{8}{500}$ Y (see 2.2)

Let δ_{max} be the maximum declination of sun, and therefore $\phi (= \delta_{max})$ is the latitude of observer situated at O.

$\therefore 90° - \delta_{max} = 720$ Y ... ...(3.2-3)

We also know that sun moves from the innermost maṇḍala (diurnal circle on Summer solstice day) upto the outermost maṇḍala

(diurnal circle on Winter solstice day) over a distance of 510 Yojanas and vice versa.[14] (see 5.1)

$\therefore 2\,\delta_{max}=510$ Y ... ...(3.2-4)

Solving eq. No. (3.2-3) and eq. No. (3.2-4), we have

$\delta_{max}=23°.54$

$=23°.5$ approx. ... ...(3.2-5)

=Latitude of observer situated at O (see eq. No. 3.2-2)

Therefore the result obtained in eq. No. (3.2-2) bears a consistency upon the validity of our assumptions.

So the following conclusions may be derived as :

(1) The flat earth OFJC is inclined to the equatorial plane at angle$=\angle$FOW

$=\angle$FAJ ($\because$ Angle between two planes is equal to angle between their normals).

$=2°.61$

(2) The circumference of Jambūdvīpa coincides with the parallel of maximum declination of sun. The axis of Meru is instanteneously taken such that OJ=50000 y whereas O lies anywhere on the parallel of maximum declination (23°.5) of the sun. Earth's true axis passes along the hypotenuse of approximate cone of Meru, and not along axis of Meru. So true radius of Jambūdvīpa (isle of Jambū tree) is equal to apparent radius of Jambūdvīpa less radius of Meru's base on flat earth (see fig. No. 3.2-3).

(3) Meru represents an astronomical model implying a notion of altitude of the celestial north pole. The altitude of the celestial north pole for an observer situated at a latitude equal to maximum declination of the sun is equal to the obliquity of eliptic. Thus the concept of Meru implies a notion of obliquity of ecliptic. This view is further supported by the fact that the famous Kutubamīnāra in Delhi situated at 28° 31′ 28″ north latitude is inclined at an angle of 5° 1′ 28″ to the vertical. Thus the noonshadow length is zero on summer solstice day.[40] Therefore it implies a

notion of maximum declination of the sun. It is quite probable that the designer of Kutubamīnāra was in possession of the knowledge of the concept of Meru as implied in Jaina canonical literature and and he attempted to perpetuate the idea by transforming the imaginary Meru into a realistic model of Kutubamīnāra in Delhi.

(d) *Applications of the Astronomical Model of Meru*

(1) From eq. No. (3.2-4) and eq. No. (3.2-5), we have

$510\ Y = 2\ \delta_{max} = 47^{0}$ $\quad (\because \delta_{max} = 23^{0}.5)$

$= 47 \times 69^{0}.09$ miles $(\because 1' = 6080\ ft)$

$\therefore 1\ Y = 6.37$ miles ... ...(3.2-6)

This is almost in accordance with the relation between a Yojana and the British miles as prevalent in those times.[25] (for more details, see 2.2).

(2) It is evident from above that the celestial angular distance had been measured into Yojanas (or yojanas) projected over the surface of earth. Yojana (or yojana) is basically a linear measure of length and it is quite confusing with the notion of modern degrees of arc.

(3) SP.18 states as : (Quotation No. 3.2-2)
"From the 'samatala bhūmi' (earth having plane surface), sun moves at a height of 800 Yojanas."

It is explicitly mentioned in JP.10.6 also.

We know that[25]

$$1\ Y = \frac{500}{8}\ y \text{ (see 2.2)}$$

$$\therefore 800\ Y = 50000\ y = OJ$$

Thus on Summer solstice day when sun lies overhead of an observer situated at O, the point J lies on the circumference of 'samatala bhūmi' (earth having plane surface). Since the sun always remains at a distance of 800 Y from 'Samatala bhūmi'; thus as the sun moves on ecliptic, J correspondingly describes an imaginary locus such that OJ remains always equal to 800 Y. This imaginary

locus corresponds to the periphery of 'samatala bhūmi' and its plane is parallel to the plane of ecliptic (apparent annual path of the sun).

Now using eq. No. (3 2-3) and eq. No. (3.2-4),

we have $OJ=800\ Y=73°.7$ ... ... (3.2-7)

$\therefore$, Celestial latitude of the point $J=OJ=73°.7$

So 'samatala bhmūi' (earth having plane surface) represents the plane parallel to the plane of ecliptic and bounded by the parallel of celestial latitude of 73°.7. The centre of 'samatala bhūmi' (earth having plane surface) is coincident with the projection (on earth) of pole of ecliptic. Radius of 'samatala bhūmi' is equal to '90° minus 73°.7' i.e. 16°.3. Obviously, concept of 'samatala bhūmi' implies a notion of obliquity of ecliptic Incidentally, with this concept of 'samatala bhūmi' the Jainian notion that moon is 80 Y higher than sun becomes easily discernible. This implies a notion of celestial latitude of moon[11] and it has been treated at length in S 3.3. Besides it may be noted that radius of Meru is equal to height of the moon over that of the sun above 'samatala bhūmi' (earth having plane surface,' denoting circular area with centre at the projection of pole of ecliptic), because height of the moon above the sun is.

$$80\ Y = 5000\ y\ (\because 1\ Y = \frac{500}{8}\ y)$$

= radius of Meru's base on flat earth.........(3.2-8)

Therefore when the moon is at maximum northern latitude, its distance from the periphery of samatala bhūmi will be 800 less 80 Yojanas. This is sun's distance from earth's true axis on Summer solstice day. Thus sun's distance from earth's true axis on Summer solstice day is equal to moon's distance (when moon occupies maximum northern latitude) from Meru's tentative axis which lies on the periphery of 'samatala bhūmi' ('earth having plane surface,' denoting circular area with centre at the projection of pole of ecliptic) (see fig. No. 3.3-1). Thus it is quite probable that the notion of latitude of moon, albeit inadequately, might have led towards the choice of radius of Meru.

Incidentally, it is worth noticing that the inclination of

KutubamInāra in Delhi is almost equal to the inclination of lunar orbit to ecliptic. Probably the place of KutubamInāra in Delhi was therefore particularly chosen for linking the notion of maximum latitude of the moon with inclination of KutubamInāra. The link of dimensions of KutubamInāra in Delhi with those of the Jaina model of Meru (see 3.2a) lends further support to our view that the radius of Meru on flat earth might have been taken as equal to maximum latitude of moon (height of the moon above the sun). It is worth noticing that the inclination, of Kutubamīnāra incorporates an almost correct value of maximum latitude of the moon, so the construction of KutubamInāra in Delhi may be antiquated to a period when correct value of maximum latitude of the moon became known This may be a period of the advent of Siddhāntic astronomy or the fag end of Jaina astronomy. As several Jaina texts have become extinct by this time, so some more investigations are yet to be made in order to ascertain the antiquity of KutubamInāra in Delhi.

In our conclusory opinion, it may be remarked that the only characteristics for 'samatala bhūmi' as referred in the text is that the sun remains above it always at a height ('celestial co-latitudinal distance' as implied in Jaina texts) of 800 Y. However the consistency of figures 800 Y and 510 Y supports our views. Even in case of Meru, consistency of figures throughout gives a good criterion. It is also worth-mentioning that although the apparent geometry confirms their notion about the shape of earth, yet the actual observation and determinations do fit the real factual geometry of earth. Language of original texts of Jaina canon is very dubious and confusing ; however our results forming a consistent picture prove our acts.

3.3 *NOTION OF CELESTIAL LATITUDE IMPLIED IN THE CONCEPT OF HEIGHTS OF JYOTIṢIKAS (ASTRAL BODIES)*

This section reveals that the word 'height' as implied in Jaina canonical literature, implies a different concept other than the traditional notion of vertical distance above earth. The very fact has been the root cause for the disillusion about the concept of height of Jyotiṣikas (astral bodies) above samatala bhūmi' (earth having plan surface' denoting circular area with centre at the pro-

jection of pole of ecliptic). It is exposed that notion of celestial latitude is implied therein.

(a) *Heights of the sun and the moon in Jaina canon.*

The term 'Jyotiṣika' denotes any astral body. About the classification of Jyotiṣikas (astral bodies),
TSS. 404 states : (Quotation No. 3.3-1)

"There are five kinds of Jyotiṣikas (astral bodies), viz. the moon, the sun, grahas (planets), nakṣatras (asterisms) and tārās (stars)."

Other explicit references are :

(1) PS. pada 1

(2) BS. 5.9.17

Heights of these Jyotiṣikas (astral bodies) are stated in SP. 18 as : (Quotation No. 3.3-2)

"The lowest star moves at a height of 790 Yojanas above the most plane portion of earth. The sun moves at a height of 800 Yojanas. The moon moves at a height of 880 Yojanas. The uppermost star moves at a height of 900 Yojanas."

Other explicit references are :

(1) JS. 3.68.11

(2) JP. 10.6

Apparently it looks very strange that the moon is 80 Yojanas higher than the sun. Dixit[10] advocates in his Bhārtiya Jyotiṣa Śāstra that no stars are visible during day time when the sun shines but on the other hand, the moon moves among the stars at night. Hence it was but natural for the people to believe that because the stars are higher than the sun and the moon moves in their region, so the moon is also higher than the sun. Nemichandra Shastri[26] also agrees with this hypothesis. The Siddhāntic astronomers were not attracted to solve the mystery of this peculiar notion. As a matter of fact, we have to delve deep into the secrets of Jaina astronomical system so as to comprehend the concept of height in its true perspective.

It was conventional to measure celestial north-south angular distances in terms of corresponding linear distances projected over the surface of earth.[14] (see 3.2 d). Here the distance of Jyotiṣikas (astral bodies) have been measured from samatala bhūmi. Height of the sun is (always) 800 Yojanas above samatala bhūmi. This

suggests that samatala bhūmi denotes an area bounded by the locus of a point that remains always at a distance of 800 Yojanas from the sun's apparent path, the ecliptic, and the plane of samatala bhūmi is parallel to the plane of ecliptic. Therefore, the centre of samatala bhūmi (earth having plane surface) lies at the projection of pole of ecliptic. As we have seen in eq. No. (3.2-7) that 800 Y=73°.7 i.e angular distance between ecliptic and periphery of samatala bhūmi is 73°.7.

∴ Radius of samatala bhūmi ('earth having plane surface' denoting a circular area with centre at the projection of pole of ecliptic) = 90°-73°.7

$$= 16°.3 \quad \ldots \quad \ldots(3.3\text{-}1)$$

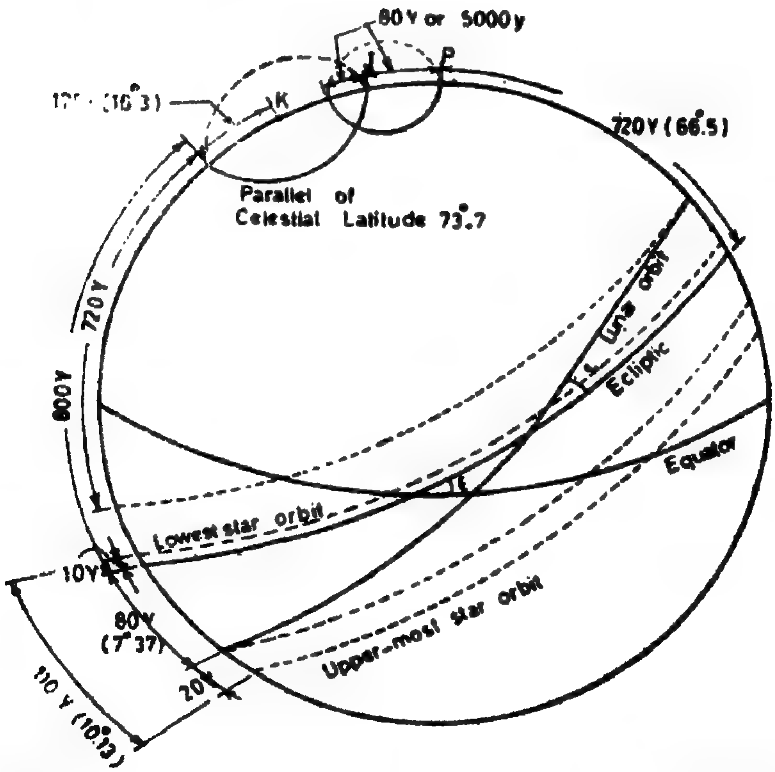


Fig. No. 3.3-1. *Notion of celestial latitude of moon implied in the concept of 'height' above samatala bhūmi ('earth having a plane surface' with centre at the projection of pole of ecliptic).*

Now from quot. No. (3.3-2), we find

height of the moon over the sun $=880-800=80$ Y

Using eq. No. (3.2-7), we have

$$80 \text{ Y} = 7^\circ.37 \ldots\ldots\ldots\ldots\ldots\ldots\ldots (3.3\text{-}2)$$

i.e. the moon is $7^\circ.37$ higher than the sun.

It may be noted here that the lunar orbit is inclined to the plane of ecliptic. When the moon lies at its ascending or descending node, its height above samatala bhūmi ('earth having plane surface' denoting circular area with centre at the projection of pole of ecliptic) is the same as that of the sun ; however the moon on its journey from descending node to ascending node remains higher than the sun with respect to samatala bhūmi. Thus according to eq. No. (3.3-2), it appears that height of the moon over that of the sun above samatala bhūmi implies a notion of maximum celestial latitude of the moon. (see fig. No. 3.3—1). However, the apparent maximum celestial latitude of the moon due to parallax[27] etc. is about $6^\circ.64$.

$$\text{Error} = 7^\circ.37 - 6^\circ.64 = 0^\circ.73$$

$$= \frac{0^\circ.37}{6^\circ.64} \times 100 = 11\%$$

On the other hand, Pauliśa Siddhānta[18] in the calculation of eclipses, presupposes the moon's greatest latitude to be 470 or $7^\circ.83$. Jaina value $7^\circ.37$ is better than that of Pauliśa Siddhānta. The error may be due to several reasons as follows :

(1) There was an immense difficulty to demarcate the ecliptic among the stars. The term 'ecliptic' derives from the fact that eclipses occur only when the moon pierces the ecliptic either towards sun (solar eclipse) or in the opposite direction (lunar eclipse).[28] Eclipses occur when longitude of the moon satisfies the condition of ecliptic limits and the moon needs not necessarily lie on the ecliptic. Thus error in the exact demarcation of ecliptic creeps in and it also influences equally the relative height of moon over that of the sun above samatala bhūmi ('earth having plane surface' denotigg circular area with centre at the projection of pole of ecliptic).

(2) The periphery of samatala bhūmi is an imaginary boundary which probably came into existence as described below :

As per eq No. (3.2—8), radius of Meru's base on flat earth is 5000 y or 80 Y which is the same as height of the moon over that of the sun above samatala bhūmi. This may not be a matter of coincidence. It may be noted that when moon traverses its journey from its ascending node to its descending node, it moves lower than sun with respect to samatala bhūmi. Compared its height over sun, the moon can move 80 Y lower than sun. As there is no star at the pole of ecliptic, it appears that firstly the relative distances of the sun and the moon were measured with respect to the pole star. Thus on Summer solstice day, if moon happens to be posited 80 Y lower than sun with respect to samatala bhūmi, a point 'J' on the great circle (projected over surface of earth) lies in between pole star and pole of ecliptic such that distance between J (point on earth where axis of Meru passes through it) and moon is the same as the distance between pole star and sun and thus sun's distance from 'J' is equal to 800 Y (see fig. No. 3.3—1). Besides the development of the concept of mount Meru implying the notion of obliquity of ecliptic, it was also conceived that corresponding to sun's annual course on ecliptic 'J' describes an imaginary circle (a parallel of latitude) circumscribing a circular area called samatala bhūmi or earth having plane surface denoting a circular area with centre at the projection of pole of ecliptic. It is worth-mentioning here that although the apparent geometry confirms their notion about the shape of earth but the actual observation and determinations do fit the real factual geometry of earth It may be quite probable that Jainas must have developed the notion of an imaginary locus of pole star such that sun remains from this imaginary locus always at a distance equal to that of pole star from sun on Summer solstice day. The radius of this imaginary locus of pole star was reduced with the development of the concept of samatala bhūmi ('earth having plane surface' with centre at the projection of pole of ecliptic). It is intended to impress upon that the heights of the sun and the moon above samatala bhūmi) were actually measured with respect to pole star which does not lie exactly upon earth's axis, hence the error in the maxi-

mum latitude of moon (height of the moon over that of the sun above samatala bhūmi)might have been caused.

(b) Heights of other Planets in Tiloya Paṇṇatti

Heights of some other planets above samatala bhūmi are also stated in Tiloya Paṇṇatti (=TP) as :[20]

Height of stars	=790 Yojanas (=Y)	(TP. 7.108)
Height of sun	=800 Y	(TP. 7.65)
Height of moon	=880 Y	(TP. 7.36)
Height of nakṣatras	=884 Y	(TP. 7.104
Height of mercury	=888 Y	(TP. 7.83)
Height of venus	=891 Y	(TP. 7 89)
Height of jupiter	=894 Y	(TP. 7.93)
Height of mars	=897 Y	(TP. 7.96)
Height of saturn	=900 Y	(TP. 7.99)

Using eq. No. (3.2-7), heights (maximum latiudes) of planets over that of sun with respect to samatala bhūmi can be easily computed into degrees of arc which are shown in table No. (3.3-1).

TABLE NO 3.3.1

Heights of Jyotiṣikas (Astral Bodies) over that of the sun above Samatala Bhūmi ('Earth Having plane Surface' Denoting Circular area with centre at the Projection of pole of Ecliptic)

I	II	III	IV	V	VI
Sr. No.	*Planet*	*Height over sun (Yojanas)*	*Maximum latitude (Degrees of arc)*	*Modern value of inclination of orbit to the ecliptic.*	
				Geocentric (Degrees of arc)	*Heliocentric (Degrees of arc)*
1.	Moon	80	7°22′	5°15′	5°9′
2.	Mercury	88	8°7′	2°42′	7°00′ 10″.37+ 6′.7T*
3.	Venus	91	8°23′	≈from 2°27′ to 7°0′	3.23′37″+3″.6 T
4.	Jupiter	94	8°40′	1°18′	1°18′31″−20″.5T
5.	Mars	97	8°56′	1°51′	1°51′ 1″−2″.4T
6.	Saturn	100	9°13′	2°29′	2°29′33″−14″.1T

*T is measured in Julian centuries from 1900.0 A.D.

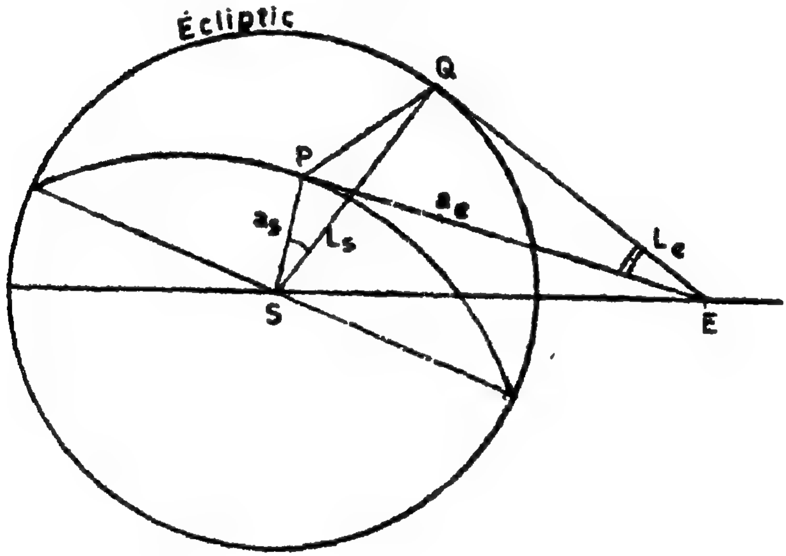
It may be seen that the order of planets is not geo-centric, note that jupiter and mars are in their interchanged positions.

It is clear from table No. (3.3-1) that heights of all the planets do not correspond to their maximum celestial latitudes respectively. It may however be noted that all planets are never visible in the order of their maximum latitudes. It is only that relative observations were made, and then put together such as described below ;

(1) Probably mercury was observed at its maximum southern latitude when moon was situated at its maximum northern latitude. Thus mercury is southwards to moon by 5°15′ plus 2°42′ i.e 7°57′ (see column No. V) which is very near to Jaina value of maximum latitude of mercury i.e. 8°7′ (see column No. IV). Consequently, mercury was understood to be 8°7′ or 88 Yojanas higher than moon.

(2) There is a great fluctuation in the geocentric latitude of venus.

Let S, P and E denote the positions of sun, planet and earth respectively. (see fig. No. 3.3-2)



SP=a_s =Radius vector of the planet with respect to the sun.
EP=a_e =Radius vector of the planet with respect to the earth.

S=Sun E=Earth P=Planet

∠PSQ=L_s= Heliocentric latitude of P.

∠PEQ=L_e=Geocentric latitude of P.

Fig. No. 3.3-2. *To find relation between geocentric and heliocentric latitudes of a planet, say, venus.*

Let a_s=Radius vector of planet with respect to sun,

a_e=Radius vector of planet with respect to earth,

L_g=Geoc·entric latitude of planet,

L_h=Helio·centric latitude of planet.

Then we have

$$\text{Tan. } L_g = \frac{\text{Sin } L_h \times a_s}{a_e} \ldots\ldots\ldots\ldots\ldots (3.3\text{-}3)$$

We find from Graha Gaṇita.[30] for the the planet venus that

$a_e \approx$ from 1.723 to .277 A.U.

and $a_s \approx$ from .7183 to .7283 A U.

Using eq. No. (3.3-3), it may be easily seen that for venus.

$L_g \approx$ from 2°27′ to 7°0.

Thus it is quite probable that mercury might have been observed with respect to venus such that the latter was 3 Yjoanas (O°16′.6) higher than the former.

(3) The relative heights of jupiter, mars and saturn are partly justified. From column V, we find that geocentric maximum latitude of mars is greater than that of jupiter by 33′ and that of saturn than that of mars by 38′; in column No. IV, these values are about 16′ or 17′. The error may be due to approximation of relative heights.

(4) A serious error has crept in noting the relative height of jupiter over that of venus with respect to samatala bhūmi. In fact, the minimum of the values of maximum latitude of venus is 2°27′ which is greater than maximum latitude of jupiter i.e. 1°18′ (see columm V). Probably at the time of observation jupiter might have been at its maximum southern latitude and venus lower to it with respect to samatala bhūmi. The discrepancy so caused in these observations seems to have been overlooked and was not rectified.

It seems that the relative observations in different groups of

planets were put together and discrepency therein may be attributed to the following reasons :

(1) Mercury is very rarely seen. Whenever it was seen, probably it happened to be at a large distance from moon as explained earlier. The discrepency could not be rectified probably because of rare visibility of mercury. The error in the value of maximum latitude of mercury is 8°7′ minus 2°42′ i.e. 5°25. This error was probably relatively added to the values of maximum latitudes (heights above samatala bhūmi) of all other planets onward.

(2) The observations of relative heights of planets were not made with respect to a single Jyotisika (astral body), say moon. By doing so, they would have grasped the whole picture in its true perspective. Because mercury is very rarely seen and other planets also become combust at different times, the need for observing their heights with respect to a single Jyotiṣika (astral body) might have not been given priority.

Besides, the given data clearly hint upon some results given below :

(1) The whole pattern of Jyotiṣikas (astral bodies) is spread over '900 minus 790' (=110) Yojanas.
Using eq. No. (3.2-7), we find that
110 Y=10°8′... ... ... (3.3-4)

On the other hand, we know that geocentric latitude of moon is 5°15′ (see column V).

∴ Belt of lunar zodiac=10°30′

∴ From eq. No. (3.3-4), it is evident that the whole pattern of Jyotiṣikas (astral bodies) is spread over the belt of lunar zodiac demarcated by the lowest and the uppermost stars (see quot, No. 3.3-2), Hnwever, accordiug to TP version[32], saturn appears to be the uppermost star.

Consequently scholars will accept that a trend towards the notion of celestial latitude is clearly implied in the concept of

heights of Jyotiṣikas (astral bodies) above samatala bhūmi (earth having plane surface' denoting circular area with centre at the projection of pole of ecliptic). Notion of belt of lunar zodiac depicts a conspicuous sign of notion of latitude of moon. Such an attempt seems tout a fait peculiar to Jainas Be it noted that Babylonians had also a notion of latitude of moon as Neugebauer[31] has shown graphically employing a zigzag function.

(2) The height of planets increases by three Yojanas from mercury to venus and uniformly so on to jupiter, mars, and saturn respectively. The smallest variation in height of Jyotisikas (astral bodies) is three Yojanas (0°16'.c) which reflects upon minuteness of a naked eye observation That is why probably they rounded off the variation in height to three yojanas instead of using lesser lengths. In the light of this discussion it cannot be envisaged that Jainas might have distributed the relevant distance in a linear zigzag manner among the planets from mercury to saturn.

It is worthy of note that L.C. Jain[29] has taken heights of Jyotiṣikas (astral bodies) as their vertical heights above earth. In the light of foregoing discussion in this section, such a concept of vertical height of Jyotiṣikas (astral bodies) cannot be accepted. Besides in the context of Jainian concept of height implying a notion of celestial latitude, it is meaningful to say that moon is 84 Yojanas higher than sun with repect to samatala bhūmi ; this notion had played an important role in making a choice of radius of Meru's base on flat earth. The error in maximum height 80 Y of moon over sun with respect to samatala bhūmi was rectified later in the development of notion of belt 110 Y of lunar zodiac. Other planets were then placed inside this belt.

CHAPTER IV

The Science of Jaina Sciatherics

4.1 INTRODUCTION

A clock is simply a mechanical device to indicate the speed of earth's rotation and it informs us of the sub-divisions of time.[1] Clepsypdra (water clock), sand clock starclock and gnomon (śaṅku, in Sanskrit) etc. were the rimordial devices to measure time. However gnomon emerged as a prominent tool of astronomy and it had its utility also in several allied astronomical computations till late medieval times.[14] Consequently a number of types of gnomon have come into existenee. There are nine broad classes of gnomons or sun-dials with style arranged to point to the celestial pole (parallel to the earth's axis), named according to the position taken by the plate or to the general form of the surface onto which the shadow is cast, viz.[2]

1. Horizontal dials
2. Reclining dials
3. Vertical dials facing south and north
4. Vertical declining dials
5. Direct east and west vertical dials
6. Polar dials
7. Equatorial and Armillary dials
8. Spherical dials
9. Cross and star dials.

Besides, there are three more types of gnomons in which the style does not point to the celestial pole, viz.[2] the analemmatic dials, the pillar dial and the portable card dial.

Now leaving aside the later trends in science of sciatherics (gnomonics), let us ponder over theory of its origination. Probably the shadow cast by some obstruction to sun's rays was used by all primitive peoples At first it is probable that a

prominent tree, a rock or a hill was selected, but in due time an artificial gnomon was erected and lines were drawn on earth to mark off the shadow.[3] Sarton[4] remarks in this context as :

> "Any intelligent person, having driven his spear into sand, might have noticed that its shadow turned. The gnomon in its simplest form was the systematization of that casual experiment."

However as regards the primitive use of gnomon, it is said that Anaximander (c.610 - 545 B.C.) of Miletus, a junior contemporary of Thales, was the earliest Lonian philosopher who erected near Sparta the first gnomon in Greece.[4] It was probably the form of an obelisk, a mere post placed perpendicular to the apparent plane of earth's surface, and not the triangular form later in use.[3] In ancient China also, sun's shadow at noon used to be observed for meridian passage whereas upper and lower transits across the meridian of the various circumpolar stars were observed at night.[5] In India we find the earliest use of gnomon in Attareya Brāhmaṇa[6] (at least 600 B.C.) in connection with observation of solstices.

By measuring length and direction of shadow of gnomon, ancients determined length of year and time of day in order to perform their religious rites at proper times. In Ceylon, each Buddhist monk is supposed to keep a calendar (lita) from which he learns the awach-hāwa (length of shadow, by which, according to rules laid down, varying with time of the year, hour of the day, may be known the age of moon, the years that have elapsed since the death of Buddha).[7] The knowledge of astronomy, as Sānticandragana states in his preface to his commentary on Jambūdvīpa Prajñapti, was an indispensable accomplishment on the part of a Jaina priest who was to decide the right time and place of religious ceremonies.[8] Incidently it may be remarked that computation of positions of sun and moon from the gnomonic shadow-length and vice versa had practical utility in the social and religious life of the people down upto the mediaeval times.[24] It is worthy of note that three kinds of gnomonic experiments were performed in ancient India.[9] viz.

1. Firstly, according to Atharva Vedic gnomonic text, day (daylight) is divided into fifteen parts called 'muhūrtas,' and shadow-lengths are given corresponding to them respectively. It has been found on analysis that shadow-length was expressed as a function of time and thus muhūrta (forty-eight minutes) had been standardized as a fundamental unit of time.[9] An exhaustive treatment of this gnomonic experiment is out of scope of this exposition.
2. Secondly, Jainas measured time as a function of shadowlength and they could compute time of day by measuring shadow—length of a gnomon.
3. Thirdly, seasons were determined through the science of sciatherics in Jaina School of astronomy.

Thus Jainas had made some remarkable advancements in the science of gnomonics. Second and third types of gnomonic experiments are peculiar to Jaina School of astronomy.

4.2 TIME OF DAY MEASURED THROUGH SHADOW LENGTHS

Here it is proposed to analyse gnomonic data bearing a relation between shadow-lengths in units of puruṣas (literally, man-lengths) and parts (fractions) of the day elapsed at various instants. In this context, SP. 9 states as :

i e. "Sun produces a shadow-length greater than 59 puruṣas (man-lengths).

Q. How much day is elapsed at a shadow-length of ½ puruṣa and how much at balance ?

Ans. One-third part (of day) is elapsed and the rest as balance.

Q. How much day is elapsed at a shadow length of one puruṣa and how much at balance ?

Ans. One-fourth part is elapsed and the rest as balance.

Q. How much day is elapsed at a shadow length of 1½ puruṣas and how much at balance ?

Ans. One-fifth part is elapsed and the rest as balance.

Q. Increasing the shadow and the (corresponding) part of day elapsed in this way, how much day is elapsed at a shadow length of 58½ puruṣas and how much at balance ?

Ans. 1/119th part is elapsed and the rest as balance.

Q. How much day is elapsed at a shadow length of 59 puruṣas and how much at balance ?

Ans Nil part is elapsed and the whole day as balance."

The above correspondence between shadow-lengths in units of puruṣas (man-lengths) and respective parts of day elapsed at various instants is shown in table (4.2–1).

TABLE 4.2-1

TABLE OF SHADOW-LENGTHS AND CORRESPONDING PARTS OF DAY ELAPSED AT VARIOUS INSTANTS

P (Shadow-lengths in units of puruṣas)	1/2	1	1½	....	58½	59
D_p (Corresponding parts of day elapsed at respective instants)	1/3	¼	1/5	....	1/119	Nil

It is obviously seen by inspection that shadow—lengths in units of puruṣas form an arithmatical progression with a common difference ½. The corresponding parts of day elapsed at various instants form a harmonic progression such that the denominators form arithmatical progression with a common difference one upto last but one term. By inspection the relation between shadow lengths in units of puruṣas (man-lengths) and parts of day elapsed at respective instants of day elapsed at respective instants can be mathematically put as

$$\left.\begin{aligned} D_p &= \frac{1}{2(1+p)} \text{ for } \tfrac{1}{2} < p < 58\tfrac{1}{2} \\ &= 0 \text{ for } p > 59 \end{aligned}\right\} \ldots\ \ldots\ \ldots(4.2-1)$$

Where D_p=Part of day elapsed

$$=\frac{1}{N_1} \text{ such that } N_1 \in \{3, 4 \ldots\ldots\ldots 119, \infty\}$$

p=Shadow-length in unils of puruṣes (man-lengths)

$$=\frac{N_2}{2} \text{ such that } N_2 \in \{1, 2, 3 \ldots \ldots \ldots 118\}$$

and there is a one-one correspondence between $\{D_p\}$ and $\{p\}$. So, btween any two consecutive instants corresponding to p and $p+\frac{1}{2}$, length of the time-interval t_p is given as

$$t_p=D_p-D_{p+\frac{1}{2}}$$

$$=\frac{1}{2(1+p)}-\frac{1}{2(1+p+\frac{1}{2})} \text{ day}$$

$$=\frac{1}{2(1+p)\ (3+2p)} \text{ day} \ldots\ldots\ldots\ldots\ldots (4.2-2)$$

Now let the velocity (variation with regard to time) of p be denoted by v_p. It is obvious from table (4.2−1) that shadow increases by a length of $\frac{1}{2}$ puruṣa per t_p (length of time interval between two consecutive instants when shadow-lengths in units of puruṣas are p and $p+\frac{1}{2}$ respectively).

$\therefore\ v_p=\frac{1}{2}$ puruṣa/t_p

Using eq. No. (4.2−2), we have

$$v_p=(1+p)\ (3+2p) \text{ puruṣas/day} \qquad \ldots\ldots (4.2\text{-}3)$$

Similarly from eq. No. (4. 2-2) and eq. No. (4.2-3), we have

$$t_{p+\frac{1}{2}}=\frac{1}{2(3+2p)\ (2+p)} \text{ day}$$

and $v_{p-\frac{1}{2}}=(3+2p)\ (2+p)$ puruṣas/day

$$\therefore \Delta t_p = t_{p+\frac{1}{2}} - t_p = \frac{-1}{2(1+p)(3+2p)(2+p)} \quad \ldots(4.2-4)$$

and $\Delta v_p = v_{p+\frac{1}{2}} - v_p = (3+2p)$ purusas/day/t_p

$$= 2(1+p)(3+2p)^2 \text{ puruṣas/day}^2 \ldots\ldots\ldots(4.2\text{-}5)$$

Thus as p increases from $\frac{1}{2}$ to $58\frac{1}{2}$, v_p increases with an increasing acceleration v_p: and length of time interval t_p between two consecutive instants decreases accordingly. Thus t_p is minimum and v_p is maximum near sunrise where p is of the order of its maximum value. Now it is evident that the above empirical relation embodying the Jaina gnomonic data stands true for all physical situations in the gnomon experiments and is quite informative for the kinematics of gnomonic shadow. It will however be revealed in the forth coming paragraphs that p has some functional relationship with actual shadow length S of gnomon.

Now let us discuss how they might have arrived at these results through simple kinematical studies of gnomon.

The primitive man must have speculated the empirical relation that D_p (part of day elapsed at any instant) increases proportionally as the actual shadow-length S decreases from morning till noon. Mathematically it may be put as

$$D_p \propto 1/S$$

or

$$D_p = \frac{K}{S} \ldots\ldots\ldots\ldots\ldots(4.2-6)$$

where K is a constant of proportionality.

Incidently, it is worth mentioning here that this empirical relation is parallel to Babylonian relation found in second table of the series mul Apin,[28] i.e.

$$t = \frac{c}{s}$$

where t = time after sunrise measured in time degrees

$(1^d = 24^h = 6{,}0^\circ)$

s=Shadow-length measured in cubits

and c=Constant.

It will however be found in the subsequent paragraphs that Jaina gnomonic text seems to be independent of any Babylonian influence.

Now applying initial conditions at the time of sunrise, $D_p=O$, $S=\infty$; we find from eq. No. (4.2−6) that K is indeterminate. So the relation (4.2−6) cannot hold for this case.

But at noon, $D_p=\frac{1}{2}$, $S=S_o$ (noon-shadow-length).

∴ From eq. No. (4.2-6), we have

$$K=\frac{S_o}{2}$$

∴ Equation No. (4.2-6) may be written as

$$D_p=\frac{1}{2}\frac{S_o}{S}\quad\ldots\ldots\ldots\ldots\ldots(4.2\text{-}7)$$

Let S_e=Shadow-excess over noon-shadow-length.

∴ At any instant, $S_e=S-S_o$ ....(4.2-8)

So from eq. No. (4.2-7) and eq. No. (4.2-8), we have

$$D_p=\frac{1}{2\left(1+\frac{S_e}{S_o}\right)}$$

or

$$D_p=\frac{1}{2(1+p)}\quad\ldots\ldots\ldots(4.2\text{-}9)$$

Provided,

$$p=\frac{S_e}{S_o}\quad\ldots\ldots\ldots\ldots(4.2\text{-}10)$$

Thus p is ratio of shadow-excess over noon-shadow-length and noon-shadow-length. Fq. No. (4.2-10) may also be written as

$$S_e=pS_o$$

or

$$S_e = p \text{ noon-shadow-lengths} \ldots\ldots\ldots\ldots\ldots (4.2\text{-}11)$$

On putting, $p = \frac{N_2}{2}$ such that $N_2 \in \{1,2,3,\ldots\ldots\ldots\ldots 118\}$,

we get

$\{S_e\} = \left\{ \frac{N_2}{2} : \frac{N_2}{2} \right.$ represents shadow-excess over noon-shadow-length, in units of noon-shadow lengths. }

$= \{\frac{1}{2}, 1, 1\frac{1}{2} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots 58\frac{1}{2}, 59\}$

$= \{p : p$ is measured in units of noon-shadow-lengths$\}$

However, from table No. (4.2-1), we find that numerically

$$\{S_e\} = \left\{ \frac{N_2}{2} : \frac{N_2}{2} = p \text{ puruṣas} \right\}$$

$= \{p . p$ is messured in units of puruṣas (manlengths)$\}$

Thus with this exposition, it is evident that

$\{p : p$ is measured in units of noon-shadow-lengths$\} =$
$\{p : p$ is measured in units of puruṣas$\}$

provided,

p noon-shadow-lengths = p puruṣa

or

noon-shadow-length = 1 puruṣa

Thus puruṣa as a unit of length may be defined as noon-shadowlength of gnomon. The idea behind calling noon-shadow-length of gnomon as unit puruṣa (man-length) might have probably been due to the following factors :

1. Firstly, the primitive man might have noted his own shadow-lengths or those of a stick of his own size from sunrise to sunset and found that noon-shadow-length is

the minimum. Thus he might have taken it as a yard. stick for measuring shadow-lengths on a particular day. It was called puruṣa (man-length) probably because it represented the minimum shadow-length of a puruṣa (man or stick of his own size) from sunr se to sunset.

2. Secondly, noon-shadow-length was called puruṣa (man-length) probably because it might have equalled the actual length of puruṣa (man or a stick of his own size). This situation however refers to a particular latitude of observer on a particular day of year. So this view is not much dependable.

   Besides, it is contemplable that the word meaning 'excess' over noon-shadow-length might have been dropped after its repeated use and consequently shadow-excess over noon-shadow-length was simply called as shadow-length in units of puruṣas (noon shadow-lengths). So the term P=O traditionally denoted noon shadow-length to be zero wheras actully it represented shadow-excess over noon-shadow-length to be zero. Thus probably to inundate the confusion about noon-shadow-length the term p=O was not include d in the SP text.

However, it is also worth mentioning that the above treatment does not hold for noon-shadow-length S_o to be zero because then p becomes infinite (see eq. No. 4 210) in all cases and D_p becomes zero (see eq. No. 4.2-9). This suggests that latitude of observer must be greater than declination of sun on the day of observation. Now let us compute the latitude of observer.

Let

z=zenith-distance of sun

δ=declination of sun

ϕ=latitude of observer

G=length of gnomon

S=Shadow length

S_o=noon-shadow-length

H=hour angle of sun

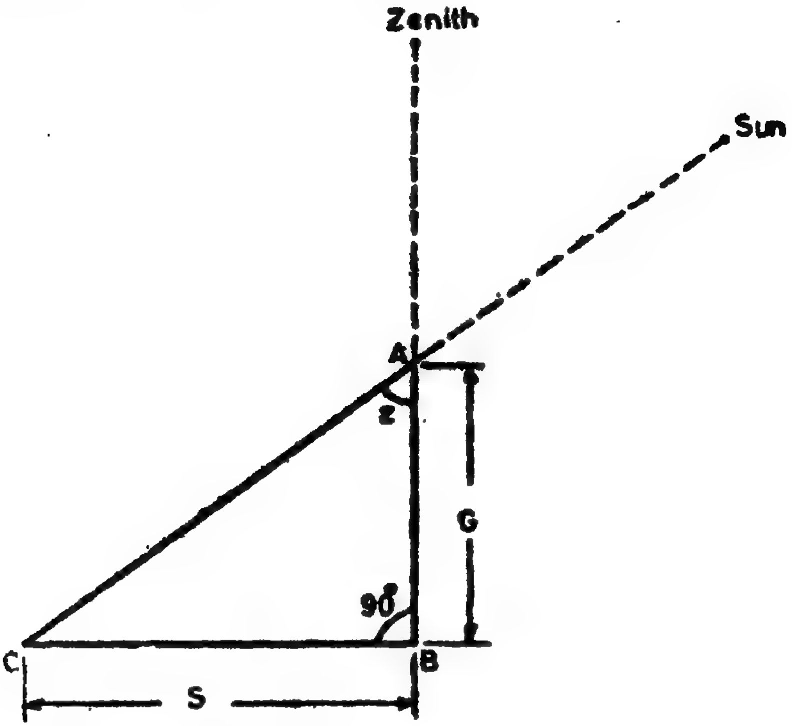


Fig. No. 4.2-1. Gnomon.

G = Length of the gnomon AB.
S = Shadow – length.
Z = Zenith distance.

$\therefore$ It may be easily seen (see fig. No. 4.2-1) that

$$S = G \tan z \quad \ldots\ldots (4.2\text{-}12)$$

$\because$ At meridian passage of sun, $z = \phi \sim \delta$

$$\therefore\ S_o = G \tan(\phi - \delta) \quad \ldots\ldots (4.2\text{-}13)$$

putting S and S_o in eq. No. (4.2-7), we have

$$D_p = \frac{1}{2} \frac{\tan(\phi \sim \delta)}{\tan z}$$

$$= \frac{1}{2} \frac{\tan(\phi \sim \delta)\ \cos z}{\sqrt{1 - \cos^2 z}} \quad \ldots\ldots (4.2\text{-}14)$$

where $\cos z = \sin\delta \sin\phi + \cos\delta \cos\phi \cos H$

(cosine fonmula)

Since length of Equinoctial day is the same for any latitude of observer, thus as a special case, let us suppose that the gnomon experiment was performed on the Equinoctial day when sun's declination δ is zero.

$\therefore$ Eq. No. (4.2-14) may be written as

$$D_p = \frac{1}{2}\frac{\tan\phi\cos z}{\sqrt{1-\cos^2 z}} \quad \text{where } \cos z = \cos\phi\cos H$$

$$\text{or} \quad D_p = \frac{1}{2}\frac{\sin\phi\cos H}{\sqrt{1-\cos^2\phi\cos^2 H}} \quad \ldots\ldots\ldots\ldots \text{(4.2-15)}$$

It may be easily computed from eq. No. (4.2-15) that

when $H=30°, 45°, 54°, 60°$,

$D_p = \frac{1}{3}, \frac{1}{4}, \frac{1}{5}, \frac{1}{6}$ ($\therefore$ for $\delta=0$, diurnal arc of day $=180°$ and $D_p = \frac{90°-H}{180°}$)

and $\phi=30°, 35°.3, 36°.9, 37°.8$

It is evident that it does not hold for a single latitude of observer on the equinoctial day. Likewise it can be shown that it does not hold for a single latitude of observer on any other day of the year. However if only a single observation be taken into consideration for the purpose of formulation, the observation relates to the latitude of 30° North; for two observations it lies inbetween 30° N to 35° N. The shift in the latitude of observer as evident by inspection becomes lesser and lesser as the number of observations to be taken into account is increased. Thus taking any large number of observations would not yield any far better result. So restricting ourselves upto four observations only, the best fit latitude of observer can be computed by applying the least square method[23] as follows :

Eq. No (4.2-15) can be written as

$$4D_p^2(1-\cos^2\phi\cos^2 H) = \cos^2 H - \cos^2\phi\cos^2 H \quad \ldots\ldots\ldots\ldots \text{(4.2-16)}$$

On putting $D_p^2 = x$, $\cos^2 H = y$, and $\cos^2\phi = a$,

we have, $4x - 4axy = (1-a)\,y$ ....(4.2-17)

Now let $x_1=\left(\frac{1}{3}\right)^2, x_2=\left(\frac{1}{4}\right)^2, x_3=\left(\frac{1}{5}\right)^2, x_4=\left(\frac{1}{6}\right)^2$

and correspondingly $y_1=\cos^2 30^0$, $y_2=\cos^2 45^0$,
$y_3=\cos^2 54^0$, $y_4=\cos^2 60^0$,

$\therefore\ \Sigma x=x_1+x_2+x_3+x_4='23639$

$\Sigma xy=x_1y_1+x_2y_2+x_3y_3+x_4y_4=.13534$

$\Sigma y=y_1+y_2=y_3+y_4=1.84551$

Applying least square method,
we get from eq. No (4.2-17) that

$4\ \Sigma x-4a\ \Sigma xy=(1-a)\ \Sigma y$

or $\quad .94556-.54136\ a=(1-a)\ (1.84551)$

or $\quad a=.69007$

$\therefore\quad \cos^2\phi=.69007$

or $\quad \phi=33^0.8$

Similarly the best fit latitude of observer can be easily computed for any other value of sun's declination. Standard errors can easily be shown to be small.

Could we imagine that such an empirical relation between (excess of) shadow-lengths in units of puruṣas (noon-shadow-lengths) and parts of day elapsed at respective instants might have been used throughout the year as it did not disturb seriously the general mode of life of the phople ? However, we have not come across with any such charts meant for different days of the year and for different latitudes of observer.

Besides according to the foregoing approach, the concept of puruṣa implies that a puruṣa equals noon-shadow-length of gnomon. However, according to Śulba Sūtras,[25] a puruṣa represents height of a man measured by his own finger. So a puruṣa may be easily taken as length of gnomon itself. Thus with this concept of puruṣa, we have,

noon-shadow-length $S_o=1$ purusa$=1$ gnomon-length,

From eq No. (4.2-13), we have

$\tan(\phi\sim\delta)=1$

or $\phi \sim \delta = 45°$

As special cases,

(i) On Equinoctial day, $\delta = 0$,

$\therefore$ $\phi = 45°$ North

(ii) On winter solstice day, $\delta = -23°.5$

$\therefore$ $\phi = 21°.5$ North

We leave aside the probability of observation on the Equinoctial day for an on observer situated at a high latitude of 45° N. The choice of winter solstice day is genuine because a Babylonian tablet, mul Apin[80] also states that noon-shadow-length on Winter solstice day is equal to one-gnomon length (for detailed discussion of mul Apin text, see 4.3a).

Thus the observation probably relates to Winter solstice day if the observer is situated at a latitude of 21° 5 North, very far from that of Babylon. and very near to that of Ujjainī, a seat of learning in ancient India. Therefore, which borrowed this portion from which is still an unsettled question.

Now let us see how far the relation (4. 2-1) fits the modern astronomical theory. D_p (part of day elapsed at any instant) can also be calculated as

$$D_p = \frac{H_0 - H}{2H_0} \quad \ldots\ldots (4.2\text{-}18)$$

where H_0=hour angle of rising sun.

Using cosine formula,[10] i.e.

$\cos z = \sin \delta \sin \phi + \cos \delta \cos \phi \cos H$,

we have,

$$D_p = \frac{\cos^{-1}(-\tan\delta \tan\phi) - \cos^{-1}(\cos z \sec\delta \sec\phi - \tan\delta \tan\phi)}{2\cos^{-1}(-\tan\delta \tan\phi)}$$

$$\text{or } D_p = \frac{1}{2(1+p)} \quad \ldots\ldots (4\ 2\text{-}19)$$

provided,

$$p=\frac{\cos^{-1}(\cos z \sec\delta \sec\phi-\tan\delta\tan\phi)}{\cos^{-1}(-\tan\delta\tan\phi)-\cos^{-1}(\cos z\sec\delta\sec\phi-\tan\delta\tan\phi)} \quad \ldots\ldots(4.2\text{-}20)$$

$$\text{or } p=\frac{H}{H_o-H} \quad \ldots\ldots(4.\ 2\text{-}21)$$

Thus p may be defined as ratio of hour angle of sun at any instant and hour angle past since rising of sun.

It is to be noted that p, shadow-length in units of puruṣas, can never assume a negative value.

$\therefore p \geqslant 0$

So if p=O, the relation (4.2-21) gives that

H=O

This situation corresponds to the exact meridian passage of sun. But there are certain practical difficulties in measuring the exact noon-shadow-length. Primarily the velocity of shadow near the meridian transit of sun is extremely slow. Secondly the shadow of gnomon terminates in a penumbra and gnomon does not cast a distinct shadow.[19] Thirdly a slight inclination of gnomon to the vertical causes a little alteration in shadow-lengths. Thus the exact demarcation of noon-shado length involves numerous difficulties which had also to be faced in the determination of Summer solstice day.[19] Obviously it was, of course, somewhat difficult to ascertain the exact moment of meridian transit of sun. Probably by dint of this type of consciousness, the term p=O, was discarded from the Jainian arithmatical progression of shadow-lengths in units of puruṣas (see table No. 4.2-1).

Again we have that $p>0$.

$\frac{p}{1+p} \neq 1$, (as $p \neq \infty$),

$\therefore$ p assumes values such that $O<\frac{p}{1+p}<1$

As $\frac{p}{1+p}\to 1$, it may be easily seen from eq. No. (4. 2-21)

that $\frac{H}{H_o}\to 1$ or $H \simeq H_o$.

Consquently S becomes infinitely large (asaṅkhyāta *i.e.* non-measurable but not infinite) as $\frac{p}{1+p} \to 1$.

Probably Jainas had discarded values greater than p=59, because even for p=59, we have from equation No. (4.2-21). that

$$59 = \frac{H}{H_o - H}$$

or $$H = \frac{59}{60} H_o$$

As a special case, on the Equinoctial day, $H_0 = 90°$

$\therefore H = 88°.5$

$\therefore$ Time past since rising of sun $= 90° - 88°.5$

$= 1°.5$

$= 6$ minutes.

Thus on Equinoctial day, the gnomonic experiment is started six minutes after rising of sun. The shadow is also faint and not well defined before this. Thus the shadow-length was considered infinite corresponding to p=59. Thus Jainian arithmatical progression of shadow-lengths in units of puruṣas (see eq No. 4.2-1) stands true for all physical situations.

Now it may be seen that corresponding to any value of p such that $\frac{1}{2} \leqslant p \leqslant 58\frac{1}{2}$, *z* can be computed from eq. No (4 2- 0) whereas ϕ and δ remain almost constant for the day. Then actual shadow-length *S* can be easily computed from eq. No (4.2-12) *i. e* S=tan *z*. Thus a relation between *S* and *p* can be established for the year for a given latitude of observer. Similar tables can be prepared for different latitudes of observer. Thus using the table corresponding to latitude of observer and day of the year, *p* can be had directly from *S*, the actual shadow-length in gnomon-lengths at that particular instant. Then time of day can be known from the standard relation between D_p and *p* as given in ep. No. (4.2-1). Probably similar tables based on empirical intution might have been used by Buddhist monks in Ceylon as referred to before. The analysis of the contents of these tables needs separate expositions. It is worthly of note that unit puruṣa is an arbitrary and imaginary measure of shadow-length and it corresponds to different values of actual shadow-length *S* depending upon latitute of observer and the day of year.

Therefore this scale representing a functional relation between p and D_p was intended to serve as a shadow-clok in those times.

(a) *Conclusion*

In the light of foregoing discussion, it may be contemplated that the primitive people might have conceived the reciprocal relation between D_p (part of day elapsed) and the corresponding actual shadow-length *S*. This resulted into the development of the concept of measuring shadow-excess over noon-shadow-length in units of puruṣas (man-lengths) whereas a puruṣa denoted noon-shadow-length of gnomon. Thus corresponding to various instants, shadow-excesses over noon-shadow-length measured in units of puruṣas (noon-shadow-lengths) formed an arithmatical progression which later turned to be a tentative and arbitrary scale which could be corresponded with a series of actual shadow-lengths on any day of year for any latitude of observer. Thus it could be used anywhere throughout the year. The concept of a puruṣa underwent a radical change and instead of noon-shadow-length, it denoted an arbitary length which corresponded to different lengths of actual shadow-length of gnomon on different days of year and for different latitudes of oberver. The term 'puruṣa' became rūḍha (रूढ), that is, just accepted due to continuous use and it no longer implied its grammatical meaning *i.e.* length of man (or gnomon) or minimum length of shadow (noon-shadow-length) of man (or gnomon). Thus this gnomonic text represents a shadow clock being probably used by Jaina monks like their contemporary Buddhistic fellow monks who continued its use through many centuries to come. However, how they generated these tables is still a puzzle.

It is worthy of note that Atharva Veda gnomonic experiment implied the concept of measuring shadow-lengths as a function of time and it was designed to standardize muhūrta (=48 minutes) as a fundamental unit of time in terms of shadow-lengths at different muhūrtas on the equinoctial day. The present S_p gnomonic experiment implies the converse of Atharva Vedic relation between time and shadow-lengths. Here time has been expressed as a function of shadow-length and the smallest time interval t_p corresponding

to $p=58\frac{1}{2}$, is equal to $\frac{1}{119\times120}$ day (see eq. No. 4.2-2) or about three seconds of an Equinoctial day (daylight). Besides, the smallest difference betwcen tims-intervals t_p and $t_{p+\frac{1}{2}}$ correspon-ding to $p=58$ is given as

$$\Delta t_{58} = \frac{-1}{2\times59\times119\times60} \text{ day (see eq. No. 4.2-4)}$$

$$= \frac{-3}{59} \text{ seconds approximately of an Equinoctial day.}$$

(Negative sign implies that t_p decreases as p increases)

This reflects upon their attempts to measure as small intervals of time as possible through kinematical studies of shadow-lengths with their primitive means. Besides it is worthy of note that the Babylonian relations between actual shadow-length as measured in cubits, and time t of day counted in time degrees, hold for Solstitial and Equinoctial days (as given in mul Apin text)[26]. Jainian relation between D_p and p holds good throughout the year. A detailed discussion of mul Apin[26] text is however out of scope of this work. It is contemplable that these Babylonian and Jainian attempts seem to be quite independent and comparative analysis of both these texts is in progress. Still good information is expected from these studies onwards.

4.3 SEASONS DETERMINATION

Here its proposed to expose the rationale of the Jainian approach towards determination of seasons through noon-shadow-lengths of gnomon.

In Vedic period, there were six seasons mentioned collectively, beginning with Spring. In some works like Aitareya Brāhmaṇa (AB.1.1), Hemanta and Śiśira together from ane[11] and the number of seasons reduces to five. As a matter of fact, in the absence of accurate knowledge of motions of sun and moon it was rather pro-blematic for the primitive man with his meagre means of measuring time to note the ending of one season and the beginning of the next. In Śatapatha Brāhmaṇa (SB. 1.6.3), there occurs a myth relating that the joints of the seasons were set right by means of

the Cāturmāsya Yajña, *i.e.* four monthly sacrifices.[13] This hints upon three as the number of seasons. Only three seasons are mentioned in the Jaina canonical literature also [14] Following this notion, Jaina priests have continued through ages their practice of breaking every four months their stay at a place. They stay at one place during the whole season. It is elucidated in the subsequent paragraphs that Jainas determined seasons by measuring noon-shadow-lengths of a gnomon.

Such an account of monthly variation of shadow-lengths is found in JP. JP. 9.17-19 states as : (Quotation No. 4-3-1)

"I. (1) How many nakṣatras (asterisms) are completed in the first month of varṣā (Rainy season) ?

Four nakṣatras (asterisms) are completed, viz. Uttarāṣāḍhā, Abhijit, Śravaṇa and Dhaniṣṭhā Uttarāṣāḍha remains for 14 ahorātras (days and nights), Abhijit for 7 ahorātras, Śravaṇa for 8 ahorātras and Dhaniṣṭhā for one ahorātra. During this month, sun moves with four aṅgulas pauruṣī (pertaining to puruṣa) shadow-length. Shadow-length on last day of the month becomes 2 pādas (human feet-lengths) and 4 aṅgulas (finger-widths).

(2) ...second month of Varṣā.. Dhaniṣṭhā 14 ahorātras, Śatabhiṣā 7 ahorātras, Pūrvābhādrapada 8 ahorātras, Uttarābhādrapada 1 ahorātra. In this month, sun moves with 8 aṅgulas pauruṣī shadow-length Shadow-length on last day of the month becomes 2 pādas and 8 aṅgulas.

(3) ......third month......Uttarābhādrapada 14 days (days and nights), Revatī 15 and Aśvinī one (ahorātra).

In this month, sun moves with 12 aṅgulas pauruṣī shadow-length. Shadow-length on last day of the month becomes 3 pādas.

(4) ......fourth......month——Aśvinī 14, Bharaṇī 15, Kṛttikā 1.........16 aṅgulas pauruṣī......3 pādas and 4 aṅgulas.

II. (1) ......first month of Hemanta (Spring)......Kṛttikā 14, Rohiṇī 15, Mṛgaśīrṣa 1 ahorātra.

...20 aṅgulas pauruṣī...3 pādas and 8 aṅgulas.

(2) .. second month.. Mṛgaśīrṣa 14, Ārdrā 8 Punarvasu 7, Puṣya 1 day and night.

...24 aṅgulas pauruṣī...4 pādas

(3) ...third month...Puṣya 14, Āśleṣā 1ᶜ, Maghā 1. ......20 aṅgulas pauruṣī...3 pādas and 8 aṅgulas.

(4) ...fourth month...Maghā 14, Pūrvāphālguṇī 15, Uttarāphālguṇī 1 ahorātra.

...16 aṅgulas pauruṣī...3 pādas and 4 aṅgulas.

III. (1) ...first month of Grīṣma (Summer)...Uttarāphālguṇī 14, Hasta 15, Citrā 1 day and night. ...12 aṅgulas pauruṣī... 3 pādas.

(2) ...second month...Citrā 14, Svāti 15, Viśākhā 1 day and night.

...8 aṅgulas pauruṣī...2 pādas and 8 aṅgulas.

(3) ...Third month...Viśākhā 14, Anurādhā 8, Jyeṣṭhā 7, Mūla 1 day and night.

...4 aṅgulas pauruṣī ..2 pādas and 4 aṅgulas.

(4) ... fourth month ..Mūla 14 days and nights, Pūrvāṣāḍhā 15 days and nights, Uttarāṣāḍhā 1 day and night.

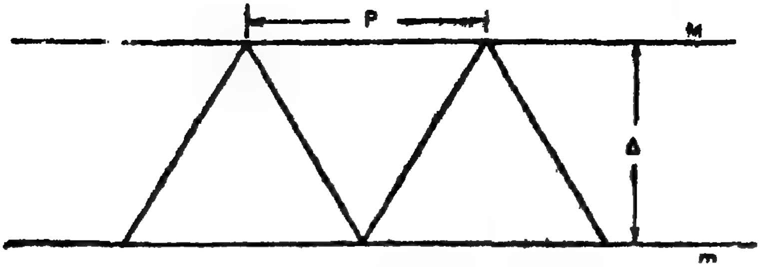
At this time sun moves with a shadow like vṛtta (circle) samacaturastra (square or rhombus) and nyagrodhaparimaṇḍala (banyan tree). Shadow-length on the last day of this month becomes 2 pādas."

This is explicitly stated in SP. 10.10 also.[18] A conspicuous picture is shown in table (4.3-1).

Table No. 4.3-1
SHADOW--LENGTHS FOR SEASONS DETERMINATION

Season	*Sr. No. of month*	*Shadow-length on the last day of the month. Pādas-Aṅgulas*	*Length of pauruṣī shadow with which the sun moves in the month Aṅgulas.*	*Nakṣatras (asterisms)* their numbers of ahorātras (days and nights) associated with the month.*
	1.	2 — 4	4	U. Ṣāḍhā 14, Abhijit, 7, Śravaṇa 8, Dhaniṣṭhā 1.
Varṣā	2.	2 — 8	8	Dhaniṣṭhā 14, Śatabhiṣā 7, P. Bhādrapada 8, U. Bhādrapada 1.
(Rainy)	3.	3 — 0	12	U. Bhādrapada 14, Revatī 15, Aśvinī 1.
	4.	3 — 4	16	Aśvinī 14, Bharaṇī 15, Kṛttikā 1.
	1.	3 — 8	20	Kṛttikā 14, Rohiṇī 15, Mṛgaśīrṣa 1.
Hemanta	2.	4 — 0	24	Mṛgaśīrṣa 14, Ārdrā 8, Punarvasu 7, Puṣya 1.
(Winter)	3.	3 — 8	20	Puṣya 14, Āśleṣā 15, Maghā 1.
	4.	3 — 4	16	Maghā 14, P. Phālguṇī 15, U. Phālguṇī 1.
	1.	3 — 0	12	U. Phālguṇī 14, Hasta 15, Citrā 1.
Grīṣma	2.	2 — 8	8	Citrā 14, Svāti 15, Viśākhā 1.
(Summer)	3.	2 — 4	4	Viśākhā 14, Anurādhā 8, Jyeṣṭhā 7, Mūla 1.
	4.	2 — 0	—	Mūla 14, P. Ṣāḍhā 15, U. Ṣāḍhā 1.

*For English equivalents, see table No. (2.3-1)



m = Minimum noon shadow—length
M = Maximum noon shadow—length
Δ = M − m
P = Time—period

Fig. No. 4.3-1. ***Linear zigzag function showing the mean rate of variation of the gnomonic noon shadow-length from Summer solstice day upto Winter solstice day and vice verca.***

It ean be easily seen by inspection that minimum m and maximum M values of paurușī (pertaining to purṣa or man-length) on last days of the months are two pādas (human feet-lengths) and four pādas respectively. The monthly increament d is four aṅgulas per mensum. Graphically (see fig. No.4.3-2), it may be conveniently computed from simple geometry that the period p of this zigzag function is given as

$$p = \frac{2\Delta}{d} \qquad \text{where} \quad \Delta = M - m$$

$$\therefore \quad p = \frac{48}{4} = 12 \text{ months } (\because \Delta = 24 \text{ aṅgulas}, d = 4 \text{ aṅgulas})$$

Besides, we also find from table No. 4.3-1 that every month consists of 30 ahorātras (days and nights).

$\therefore$ 12 months = 360 ahorātras (days and nights).

or p = 360 ahorātras

This suggests that an ahorātra (day and night) as implied herein is equivalent to a saura day which is defined as the length of time required for sun to traverse 1/360th part of the zodical

circumference. This notion is quite confusing at the first instance. Thus the zodical circumference was however graduated in 360 saura days[15] (for details, see 2.3).

The observation relates to 3rd/4th century A.D., that is, about one thousand years after Winter solstice coincided with the beginning of Abhijit (α Lyrae) nakṣatra (asterism) (see 2.3).

Besides, it is contemplable that paurusī (pertaining to puruṣa *i.e.* man or a stick of his own size) shadow-length on last day of the month pertains to the concept of puruṣa (noon-shadow-length reckoned to be minimum during whole of the day and taken as a unit of measurement of shadow-length) (for details, see 4 2). However, pauruṣī shadow-length is not defined for last month of Grīṣma (summer) but otherwise it seems to have been taken relatively as nil or the base with respect to which the total variation of pauruṣī shadow-length in other month has been computed. Thus pauruṣī shadow-length may be defined as the sum of monthly increment in the noon-shadow-length, with minimum on last day of the fourth month of Grīṣma (Summer). This also suggests that last day of the fourth month of Grīṣma (Summer) coincides with Summer solstic day. Thus noon-shadow-length on this day is actually 2 pādas (see table 4 3-1). Thus noon-shadow-length on the last day of any month and the corresponding pauruṣī shadow-length (the total increment in noon-shadow-length) may be easily computed as

Noon-shadow-length on the last day of any month	= 2 pādas + pauruṣī shadow-length ...	... ...(4.3-1)

and pauruṣī shadow-length=$4n$ aṅgulas ... ...(4.3-2)

where n = number of months since Summer solstice day or yet to go for that.

Besides, the locus of shadow on the 'last day of the fourth month of Grīṣma or Summer' (Summer-solstice day) is stated to be like vṛtta (circle), samacaturastra (square or rhombus), nyagrodha-parimaṇḍala (banyan tree) *i.e.* like the figure of a Banyann tree.[16]

Now let us compute the latitude of the observer.

Taking $\delta_{max}=23^\circ.5$ (obliquity of ecliptic), see 3.2, using eq. No. (4.2-13) we have that

$$M = G \tan(\phi+23^\circ.5)$$

$$m = G \tan(\phi\sim 23^\circ.5)$$

Putting M 4 pādas and $m=2$ pādas (see table 4.3-1), we get

$$4 = G \tan(\phi+23^\circ.5) \qquad \ldots \quad \ldots \quad \ldots \quad \ldots(4.3\text{-}3)$$

and $$2 = G \tan(\phi\sim 23^\circ.5) \qquad \ldots \quad \ldots \quad \ldots \quad \ldots(4.3\text{-}4)$$

Dividing eq. No. (4.3-3) by eq. No. (4.3-4), we have

$$2 = \frac{\tan(\phi+23^\circ.5)}{\tan(\phi\sim 23^\circ.5)} \qquad \ldots \quad \ldots \quad \ldots \quad \ldots(4.3\text{-}5)$$

Now two cases arise.

Firstly let $\phi>23^\circ.5$.

$\therefore$ From eq No. (4.3-5), we get.

$$2=\frac{\tan(\phi+23^\circ.5)}{\tan(\phi-23^\circ.5)}$$

$$=\frac{\tan\phi+\tan 23^\circ.5}{1-\tan\phi\tan 23^\circ.5}\cdot\frac{1+\tan\phi\tan 23^\circ.5}{\tan\phi-\tan 23^\circ.5}$$

Putting $\tan\phi=x$, and $\tan 23^\circ.5=c$, we have a quadratic equation in x, *i.e.*

$$3\,c\,x^2-(1+c^2)x+3c=0 \qquad \ldots \quad \ldots \quad \ldots \quad \ldots(4.3\text{-}6)$$

The determinant $\{(1+c^2)^2-36\,c^2\}$ is negative.

$\therefore$ The roots of eq No. (4.3-6) are complex.

$\therefore \phi \not> 23^\circ.5$

Secondly, let $\phi<23^\circ.5$

From eq. No. (4.3-5), we have

$$2=\frac{\tan(\phi+23^\circ.5)}{\tan(23^\circ.5-\phi)}$$

which gives, as before, quardratic equation in x, *i.e.*

$$c\,x^2-3(1+c^2)x+c=0 \qquad \ldots \quad \ldots \quad \ldots \quad \ldots(4.3\text{-}7)$$

Its roots are given as

$$x=\frac{3(1+c^2)+\sqrt{9(1+c^2)^2-4c^2}}{2c}$$

From Tables, we find

$$c = \tan 23°.5 = .43481$$

$$c^2 = .18906$$

$$\therefore \quad x = 8.08023 \text{ or } .12377$$

or $\tan \phi = 8.08023$ or $.12377$

$$\therefore \phi = 82°9 \text{ or } 7°.1$$

Since $\phi \not> 23°.5$ (proved before)

$$\therefore \phi = 7°.1 \text{ North}$$

This latitude falls in Śrī Laṅkā,[17] an integral part of ancient India.

However it may be noted that corresponding to $\phi = 7°.1$ North $\phi \sim \delta$ becomes zero twice an year, and corresponding noon-shadow-length also becomes zero.

Ii seems therefore quite plausible that maximum and minimum noon-shadow-lengths on the solstitial days might have been practically obtained but the monthly rate d of variation of noon-shadow-length was obtained through a linear zigzag funtion as

$$d = \frac{2\Delta}{p} = \frac{4}{12} \text{pādas}, \; (\because \Delta = M - m$$

$$= 2 \text{ pādas}$$

$$= 4 \text{aṅgulas} \; (\because 1 \text{ pāda} = 12 \text{ aṅgulas})$$

Subsequently the concept of pauruṣī shadow-length (total monthly increments in the noon-shadow-length) might have been developed. Such linear zigzag functions were also employed in ancient China in the former Han dynasties, till first century A D.[18]

Now let us calculate the length of gnomon.

Substituting $\phi = 7°.1$ in eq. No. (4 3-3), we have

$$4 = G \tan 30°.6$$

$$\therefore \; G = \frac{4}{.59140} \text{ pādas}$$

$$= 81.16 \text{ aṅgulas}$$

However attention may be called upon a crude measure about the length of a puruṣa ADS 149. 13.1 states as : (Quotation No. 4.3-2).

"Twelve aṅgulas of the self make one's face and nine times the length of face is equal to the length of puruṣa (man)."

This gives us that

1 puruṣa = 12 × 9 = 108 aṅgulas

According to A. K. Bag,[25] puruṣa represents the height of a man measured by his own finger and according to Baudhāyana Śulba[26] (1.3-21), 120 aṅgulas make a puruṣa

Now according to this exposition, let G denote the length of a puruṣa (man) or a stick of his own size used as gnomon. Last δ_{max} be sun's maximum declination.

∴ From eq. No. (4.2-13), we have

$S_0 = G \tan(\phi \sim \delta_{max})$ ... ...(4.3-8)

On putting $\phi = 7^\circ.1$ North and $\delta_{max} = \pm 23^\circ.5$,

for G = 108 aṅgulas (ADS length of puruṣa), we have

m = 2.64888 pādas)
M = 5.32260 pādas) (4.3-9)

With 120 aṅgulas as the length of gnomon, m and M become still larger and the deviation from the given data becomes still more pronounced. Besides, it may also be recalled that the popular measure of length consisted of 96 aṅgulas. In this context, SVS. 96.3 states as : (Qutation No 4.3—3)

"In practice, the practical measure (of length) called 'Daṇḍa' (staff) consists of 96 aṅgulas."

Assuming 96 aṅgulas as the length of gnomon, i.e.

G = 96 angulas, and putting $\phi = 7^\circ.1$ and $\delta_{max} = \pm 23^\circ.5$, in eq. No. (4.3—8), we have

m = 2.35456 pādas)
M = 4.73120 pādas) (4.3—10)

Obviously standard deviations corresponding to G = 96 aṅgulas, can be easily shown to be small. Now taking length of Gnomon G to be equal to 96 aṅgulas we may compute the latitude of observer as follows :

Now apart from several factors contributing to the error in measuring noon-shadow-length (see 4.2) be it noted that lengths, m and M, have been measured into integral numbers of pādas (human feet-lengths) and an error of approximation of half a pāda is incorporated therein. Therefore the real values of m and M fall in the range as given below :

$$\left.\begin{array}{l} m \approx \text{from } 1.5 \text{ to } 2.5 \text{ pādas} \\ \text{and } M \approx \text{from } 1.5 \text{ to } 4.5 \text{ pādas} \end{array}\right\} \quad \ldots \quad (4\,3\text{—}11)$$

Let M = 4.5 pādas (Maximum possible value of M, see eq. No. 4.3—11); and sun's position corresponds to Winter solstice day,

$\therefore$ from eq. No. (4.3—8) we have

$$4.5 = 8 \tan (\phi + 23.5) \quad (\because G = 96 \text{ aṅgulas} = 8 \text{ pādas})$$

$$\therefore \quad \varphi = 5^\circ.9 \text{ North}$$

for which, m = 2.53776 pādas.

But similarly if m = 2.5 pādas (maximum possible value of m, see eq. No. 4.3—11), we get

$$\phi = 6^\circ.1$$

for which M = 4.54465 pādas.

Thus we see that as ϕ increases from 5°.9 N to 6°.1 N, m decreases from 2.53776 pādas to 2.53776 pādas to 2 50000 pādas and M increases from 4 50000 pādas to 4.54464 pādas. Therefore the optimum latitude of the observer is given as

$$\approx \text{from } 5^\circ.9 \text{ to } 6^\circ.1 \text{ N}$$

So ϕ may conveniently be taken as 6° North.

Here a passing remark may be made as regrads a fragment of an early gnomonic text preserved in SVS. In this context, SVS. 27.5 states as : (Quotation No. 4.3—4)

"On the seventh lunar day of Śravaṇa, sun gives a paurușī shadow-length of 27 aṅgulas and moves on such that the daylight decreases and the night increases."

SVS. 36.4 further states as : (Quotation No. 4.3—5)

"The sun produces a paurușī shadow-length of 36 aṅgulas in the months of Caitra and Āśvina each."

Be it noted that Spring equinox and Autumnal equinox occur in the months of Caitra (first lunar month of Hindu calendar) and Āśvina (seventh lunar month of Hindu calendar) respectively. Besides, we find that

$$\frac{m+M}{2} = \frac{2+4}{2} = 3 \text{ pādas} = 36 \text{ aṅgulas.}$$

Therefore the paurușī shadow-length of 36 aṅgulas was obtained for the equinoctial days through a linear zigzag function. Therefore the SVS text is a fragment of the gnomonic text extant in other Jaina canonical works like JP and SP as discussed earlier.

a() *A Note on mul apin gnomonic Text*

Here it is worthy of note to deem a fragment of gnomonic text extant in a Babylonian tablet mul Apin[20]. It states that noon-shadow-length on winter solstice day is equal to one gnomon length but this does not yield any value for the noon-shadow-length on Summer solstice day.

$\therefore$ From eq. No. (4.2—13), we have

$$G = G \tan(\phi - \delta) \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad (S_0 = G)$$

or $G\{1 - \tan(\phi - \delta)\} = 0$

$\because G \neq 0,$

$\therefore 1 - \tan(\phi - \delta) = 0$

$$\text{or } \phi - \delta = 45° \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad (4.3 - 12)$$

$\because$ On winter solstice day, $\delta = -23°.5$

$\therefore \phi = 21°.5$ North

A gnomonic text similar to that of mul Apin is also preserved in Arthaśāstra[21] where the noon-shadow-length of a twelve digits gnomon is twelve digits on Winter solstice day. But the noon-shadow-length on Summer solstice day is assumed to be zero, which is actually given as follows :

From eq. No. (4.2 — 13), we have

$S = 12 \tan(23°.5 - 21°.5)$

$(\because G = 12 \text{ digits}, \phi = 21°.5 \text{ N})$

$= 0.41904$ digits or slightly less than $\frac{1}{2}$ digit approximately.

This error in the noon-shadow-length on Summer solstice day was probably rectified in the Śārdulakarṇavadāna[22] (=SKV).

The SKV also gives the noon-shadow-lengths of a gnomon measuring sixteen digits, for each month in a linear zigzag function almost identical with that of the Arthaśastra; one variation in SKV is that the noon-shadow-length on Summer solstice day is half a digit rather then zero. It may be easily seen that for $\phi = 21°.5N$, G 16 digits, from eq. No. (4.2—13), we have

$$S = 16 \tan (23°.5 - 21°.5)$$
$$= .55872 \text{ digits or } \tfrac{1}{2} \text{ digit approximately.}$$

In the light of this discussion, it may be contemplated that mul Apin text relates to a latitude passing through the central India like the place of Ujjayinī which is renowned for having been an ancient seat of learning. It cannot be accepted that mul Apin text could have been adapted to suit the Indian conditions. A consistency of results regarding noon-shadow-length on Summer solstice day reveals that mul Apin text has a close relation with Arthaśāstra text and SKV text and it suits Indian conditions better.

CHAPTER V

Notion of Declination implied in the concept of Maṇḍala (Diurnal Circle)

Here an attempt has been made to probe into the concept of maṇḍala (diurnal circle), especially the solar maṇḍala (diurnal circle of sun) and lunar maṇḍala (diurnal circle of moon). It is revealed that the Jainian concept of maṇḍala (diurnal circle) alludes to the notion of declination and that a notion of spiral motion of sun and moon is also implied therein.

5.1. SOLAR MAṆḌALAS (SUN'S DIURNAL CIRCLES)

(a) Number of Solar Maṇḍalas

As regards the number of solar maṇḍalas, JP. 7.2 states as : (Quotation No. 5.1-1)

> *i.e.* ' There are sixty-five solar maṇḍalas stretched over 180 Yojanas of Jambūdvīpa (isle of Jambū-tree) and 119 solar maṇḍalas stretched over 330 Yojanas of the Lavaṇa-samudra (salt ocean). In all there are 184 solar maṇḍalas in both Jambūdvīpa and Lavaṇasamudra."

Evidently the entire stretch of 184 solar maṇḍalas is supputed as the sum of their respective stretches over Jambūdvīpa (isle of Jambū tree) and lavaṇasamudra (salt ocean).

∴ Total stretch of the solar maṇḍalas = 180 + 330
= 510 Yojanas.

(b) Linkage of Solar Maṇḍalas (Sun's Diurnal Circles) with sun's Annual Course

The mode of linking solar maṇḍalas with sun's annual course is depicted in SP.1.1.4-5 states as : (Quotation No 5.1-2).

i e. "When the sun treading upon maṇḍala to maṇḍala, moves from the innermost maṇḍala (sun's diurnal circle on Summer solstice day) upto the outermost maṇḍala (sun's diurnal circle on Winter solstice day) and from the outermost maṇḍala to the innermost maṇḍala, how much time in days and nights is required ?

The required period is 366 days and nights.

How many maṇḍalas does sun tread upon during this period-twice upon how many madṇḍalas and once upon how many madṇḍalas ?

(During this period, the sun treads upon 184 maṇḍalas-twice upon 182 maṇḍalas *i.e.* while (once) going outward (towards the outermost maṇḍala) and (then) coming inwards the innermost maṇḍala, (and) once upon two maṇḍalas *i e.* the innermost maṇḍala (and) the outermost maṇḍala."

Evidently, the exact number of solar maṇḍalas.

$=2\times 182+2=366$ ... ...(5.1-)

Thus in 366 days and nights sun treads upon 366 solar maṇḍalas.

∴ Velocity of sun across the solar maṇḍals = 1 solar maṇḍala/day (day and night) ... ...(5.1-2)

(*c*) *Distance of solar maṇḍalas (sun's diurnal circle) from Meru*

As regards the north-south distances of solar maṇḍalas from Meru, JP. 7.4-5 states as : (Quotation No. 5.1-3).

i e. "The innermost solar maṇḍala (sun's diurnal circle on Summer solstice day) is 44820 yojanas distant (from Meru). Second to the innermost maṇḍalas is $44822\frac{48}{61}$ yojanas distant (from Meru). Third to the innermost maṇḍala is $44825\frac{35}{61}$ yojanas (distant from Meru). By increasing the distanee by $2\frac{48}{61}$ yojanas per maṇḍala, the

sun (finally) reaches the outermost maṇḍala (sun's diurnal circle on Winter solstice day). The outermost maṇḍala is 45330 yojanas distant from Meru."

As we have expounded earler (see 3.2) that the mount Meru exhibits some celestial polar characteristics and earth's axis passes along hypotenuse of the approximate cone of Meru (see fig No. 3 2-2). So it seems plausible that the earth distance of any solar maṇḍala (sun's diurnal circle) from periphery of Meru's cross-section on flat earth denotes its angular distance from north pole. Probably this is why distance any solar maṇḍala is given here (see quot. No. 5.1-4) from peeiphery of base of Meru on flat earth and not from axis of Meru and this distance may therefore conveniently be called as equivalalent to north polar distance (NPD) of the particular solar maṇḍala (sun's diurnal circle) or NPD of the sun while occupying that particular maṇḍala.
Thus from quot No. (5.1-3), we have

$$\frac{d}{dt}(\text{NPD}) = 2\frac{48}{61} \text{ Yojanas/solar maṇḍala (sun's diurnal circle),}$$

Or with the application of eq. No. (5.1-2), it may be written as

$$\frac{d}{dt}(\text{NPD}) = 2\frac{48}{61} \text{Yojana/day (day and night).}$$

Integrating both sides, we have

$$\text{NPD} = \int_{o}^{n} 2\,\frac{48}{61} dt \text{ Yojanas} + c \quad \ldots \quad \ldots \quad \ldots \quad \ldots (5.1\text{-}3)$$

where c = Constant

n = Number of solar maṇḍals (sun's diurnal circles) already embraced by sun in its southern course or yet to be embraced in its northern course.

Applying inifial conditions i.e., when the sun occupies the innermost maṇḍala (sun's diurnal circle on Summer solstice day).

NPD = 44820 y, and n = 0.

∴ from eq. No. (5.1 — 3), we have

c = 44820 y

∴ Eq. No. (5.1 — 3) can be written as

$$\text{NPD} = \int_{0}^{n} 2\,\frac{48}{61} \text{ Yojans} + 44820 \text{ Y} \ldots\ldots\ldots\ldots\ldots\ldots (5.1 - 4)$$

Thus NPD of any solar maṇḍala (sun's diurnal circle projected on earth's surface) can be tout de suite reckoned from this equation. For example, when the sun occupies the outermost maṇḍala (sun's diurnal circle on Winter solstice day),

$n = 183$

$$\therefore \text{ NPD of the outermost maṇḍala} = \left[2\frac{48}{61}\right]_{0}^{183} \text{ Yojanas} + 44820 \text{ y}$$

$$= 510 \text{ Y} + 44820 \text{ y}$$

$$= \text{Numerically } 45330 \text{ y} \qquad \text{......(5.1—5)}$$

(as given in quot. No. 5.1 — 4).

The mystery of intermingling Y (Yojana, TP units) and y (ātma yojana, ADS units) (see 2.2) in the computation of NPD of any solar maṇḍala as depicted in eq. No. (5.1 — 5) will be resolved in due time as we come to this point later. The proof of pudding lies in eating.

Now it is tout a fait in the vicinity of thought that Jaina concept of maṇḍala (diurnal circle) implies a notion of NPD of solar maṇḍala or of sun occupying that particular maṇḍala. Thus notion of declination (complement of NPD) is also implied therein, though irrespective of the position of the equator.

$\therefore$ Total variation of declination = Total variation in NPD

$$= 510 \text{ Y} \qquad \text{...........(5.1-6)}$$

One may ponder over the non-algebraic character of this concept of declination i.e. the declination does not increase on both sides of the equator. This is de facto attributable to the development of Jaina peculiar notion of flat earth by virtue of which they remained aloof from developing any notion like that of equator. Their theory of ever increasing (or decreasing NPD of the solar maṇḍalas (sun's diurnal circles) in sun's southern course (or northern course) might have probably led them develop their tentative model of flat earth (see 3.1) but in due time Jainas became so convinced of the use of their false notion of flat earth in explaining their cosmic viewpoints

that they failed to take up the problem of variation of NPD de novo. Thus the notion of equator might have escaped their attention.

Now let us probe into the rationale of distribution of solar maṇḍalas (sun's diurnal circles) between Jambūdvīpa (isle of Jambū tree) and the Lavaṇasamudra (salt ocean). Vide quot. No. (5.1-1), we know that

N_l = Number of solar maṇḍalas in lavaṇasamudra = 119

N_j = Number of solar maṇḍalas in Jambūdvīpa = 65

D_j = North-south stretch of solar mandalas in Jambūdvīpa = 180 Y

D_l = North-south stretch of solar maṇḍalas in Lavaṇasmudra = 330 Y

Now because,

$$\frac{N_l}{N_j} = \frac{119}{65} = 1 + \frac{1}{1+}\,\frac{1}{4+}\,\frac{1}{6+}\,\frac{1}{2}$$

and

$$\frac{D_l}{D_j} = \frac{330}{180} = 1 + \frac{1}{1+}\,\frac{1}{5}$$

Therefore we may fairly presume by inspection that

$$\frac{N_l}{N_j} \approx \frac{D_l}{D_j}$$

Since

$$\frac{N_l}{N_j} \times D_j = \frac{119}{65} \times 180 = 329.54 \text{ or } 330 \text{ Y approximately}$$
$$= D_l \text{ (given)}$$

∴ The following relation fairly holds good, i.e.

$N_l : N_j :: D_l : D_j$ ....(5.1-7)

This leads us to the view that the north-south stretch 330 Y of solar maṇḍalas in the Lavaṇasmudra (salt ocean) might have been theoretically generated through a simple linear zigzag manner probably as shown above. This view is further evidenced by its inherent dependence upon the factual determination of the relation between number of solar maṇḍals N_j and their north-south stretch

D_J in Jambūdvīpa (isle of Jambū tree). This is elucidated as follows :

$\because$ Obliquity of ecliptic $= 23°.5$ (see 3.2)

$\therefore$ Sun's maximum declination $\delta_{max} = 23°.5$

$\therefore$ Using eq. No. (5.1-6), we have

$$510\ Y = 2\ \delta_{max} = 47° \qquad \text{.........(5.1-8)}$$

$$\therefore D_J = 180\ Y = 16°.6$$
$$= 23°.5 - 6°.9$$

It suggests that north-south stretch D_J of maṇḍalas (sun's diurnal circles) in Jambūdvīpa is extended southward from sun's extreme north position 23°.5 upto 6°.9 in the northern hemisphere as we understand it these days. This also implies that north-south stretch D_L of solar maṇḍalas in Lavaṇasamudra (salt ocean) starts from 6°.9 North, the southern limit of D_J, verisimilarly coinciding with the southern limit of ancient India including modern 'Srī Laṅkā.'[1] Besides, it may be confirmed from Nautical Almanac that declination of sun decreases from its maximum value on Summer solstice day to about 7° North in a span of about seventy-five days and to about 8°.5 North (southern limit of modern India)[1] in a span of about seventy days.[2] Thus it seems convincing that verisimilarly the southward journey of sun was measured in Yojanas starting from a station on earth where the noon-shadow-length of gnomon was zero on the summer solstice day i.e. starting from a station situated in the neighbourhood of terrestrial latitude of 23°.5 North (which is incidently very close to the latitude of Ujjain, a renowned seat of ancient Indian culture) upto the station situated at about the extreme southern limit of ancient India where again the noon-shadow-length was observed to be zero after sixty-five days since Summer solstice day. This also testifies their technique of measuring celestial angular distance in terms of corresponding distance projected over the surface of earth as depicted earlier (see 3.2). However, it is worthy of note that a small discrepancy in reckoning the number of solar maṇḍalas in Jambūdvīpa (isle of Jambū tree) to be sixty-five instead of seventy or seventy-five as ought to have been as shown above, was due to obstacles in measuring the noon-shadow-length. Several errable factors like the ending of shadow in penumbra, slow velocity of shadow length near the meridian

transit of sun and slight inclination of gnomon etc. are pertaining thereto (see 4.2). Besides it cannot be claimed with certainty as to which place on the sea coast might have been mis taken for the southern extremity of their land which was supposed to be a circular land mass surrounded by the ocean ring (lavaṇa samudra or salt ocean). (Incidently, in sixty-five days since Summer solstice day, sun's declination becomes about 10° North. This might refer to some place in modern Kerala state). Keeping in view these very factors, it is contemplable that Jainas had actually measured in Yojanas, total change in sun's declination (or variation in NPD as Jainas understood) in sixty-five solar maṇḍalas (sun's diurnal circles) in sun's southern journey starting from the innermost maṇḍala (diurnal circle on Summer solstice day). Having known the length of sun's annual course (366 days) and following the notion that each of the extreme solar maṇḍalas is traversed over only once during sun's annual course, total number of solar maṇḍalas was taken to be $\frac{366}{2}+1$ i.e. 184. N_1 $(=184-N_j)$ was easily calculated to be 119. Then D_1 might have been theoretically computed through relation (5.1-7). Further they employed a simple linear zigzag function to distribute the total north-south strech 510 Yojanas between extreme solar maṇḍalas uniformly among all the solar maṇḍalas. Thus NPD increases by $2\frac{48}{61}$ Yojanas per solar maṇḍala from innermost solar maṇḍala upto outermost solar maṇḍala and vice versa. This exhibits their inefficiency to grasp the real variation in sun's declination or NPD of solar maṇḍalas as they understood it in their terms.

Now let us make a further probe into the rationale of computation of NPD of solar maṇḍalas. It may be recalled that

Radius of Jambūdvīpa[4] (isle of Jambū tree) = 50000 y
Radius of the mount Meru's base on flat earth = 5000 y

As per our exposition of Jaina tentative astronomical model of Meru, true axis of earth passes along the hypotenuse of the approximate cone (made up of frustrum of cones) of Meru and thus the tentative axis of Meru passes through the earth at a distance of 5000 y (radius of base of Meru on flat earth) from the true axis of earth. And on the other hand, the innermost solar maṇḍala (sun's

diurnal circle on Summer solstice day) is situated 180 Y inside Jambūdvīpa (isle of Jambū tree) as is deduced from the quot. No. (5.1-1) and quot. No. (5.1-3).

∴ NPD of the innermost solar maṇḍala or its shortest distance from the periphery of Meru's base on flat earth

= (Radius of Jambūdvīpa—radius of Meru's base on flat earth)—inward distance of innermost solar maṇḍala from periphery of Jambūdvīpa.

= (50000—5000) y--180 y

= Numerically 44820 y... ... ... (5.1-9)

It may also be recalled that the tentative axis of Meru lies on the circumference of 'samatala bhūmi' ('earth having plane surface' denoting circular area with centre at the projection of pole of ecliptic) (see 3.2 and 3.3). On Summer solstice day, height (celestial co-latitudinal distance projected over surface of earth) of sun above 'samatala bhūmi' is 800 Y. Radius of Jambūdvīpa with axis of Meru passing through its centre is 50000 y. As we have expounded earlier (see 3 2) that periphery of Jambūdvīpa coincides with the parallel of maximum declination of sun, so height of sun (occupying innermost maṇḍala) above samtala bhūmi is equivalent to radius of Jambūdvīpa (distance of sun occupying innermost maṇḍala from axis of Meru) i e.

800 Y=50000 y... ... ...(5.1-10)

or $1\ Y = \frac{500}{8}\ y$

∴ 80 Y=5000 y... ... ...(5.1-11)

Subtracting eq. No. (5.1-11) from eq. No. (5.1-10), we have

720 Y = 45000 y = 50000 y — 5000 y

= Radius of Jambūdvīpa – radius of Meru

= Shortest distance of earlh's axis from periphery of Jambūdvīpa (isle of Jambū tree)

= $90^\circ - 23^\circ.5$ (∵ periphery of Jambūdvīpa concides with mximum declination δ_{max} of sun)

= $66^\circ.5$

This result is tout a fait consistent with eq. No. (5.1-8) i.e. 510 Y = 2 δ_{max} = 47° (see also 2.2 and 3.2)

In the light of these discussions, it may be contemplated that the variation of sun's declination was deliberately measured in 510Y in a manner as discussed earlier. Jainas were probably afraid of the insecurity of reckoning the variation of sun's declination from zero (corresponding to sun's position on Summer solstice day) to 510Y (corresponding to sun's position on Winter solstice day). Thus to avoid the act of defining the place of zero declination, they might have been tempted to befit these data in their pre-conceived cosmographic framework of mind. Consequently the concept of NPD of solar maṇḍala as implied in Jaina canonical texts came into existence thereby. The two Units, Y and y, were intermingled. Primarily D_J was confused with while calculating the NPD of the innermost solar maṇḍala (see eq. No. 5.1-9). This happened probably because according to their original findings, circumference of Jambūdvīpa (isle of Jambū tree) was considered to be situated 180 Y (stretch of sixty-five solar maṇḍalas in Jambūdvīpa as per Jaina canonical texts) inside the sea coast of the inhabited land; consequently the innermost maṇḍala (sun's diurnal circle on Summer solstice day) whose projection on earth coincides with circumference of Jambūdvīpa as per our exposition, was considered to be situated 180 Y inside the coast of lavaṇa samudra (salt ocean). But due to later interpolations it became customary to consider as if the innermost solar maṇḍala (sun's diurnal circle on Summer solstice day) were situated 180 Y inside Jambūdvīpa (isle of Jambū tree). Consequently the error was introduced due to subtraction of 180 Y from 45000 y (radius of Jambūdvīpa minus radius of Meru on flat earth) while calculating 'distance of innermost solar maṇḍala from periphery of Meru on flat earth' (NPD of innermost solar maṇḍala) (see eq No. 5.1-9). It is our speculation based on the dictum : Exitus acta probat (result proves the act). Secondarily, a further error crept in while the rate of variation of sun's declination from zero to 510 Y was equated with the rate of variation of NPD without making any allowance for compatibility between the two diverse scales of measurement of length. Such an intermingling of units Y (Yojana, TP units) and y (ātma yojana, ADS units) (see 2.2) has hitherto remained as a crux of immense confusion for research into this field.

(d) *Dimensions of Solar Maṇḍalas*

As regards the dimensions of solar maṇḍalas (sun's diurnal

paths), it is explicitly stated in SP. 1.8 as : (Quotation No. 5.1-4).

i.e. "All the solar maṇḍalas are $\frac{48}{61}$ Yojanas thick each.

The distance between any two (consecutive) maṇḍalas is 2 Yojanas. The distance of 510 Yojanas is to be treaded upon (by sun) in 183 days.

What is the distance between the inner limit of the innermost maṇḍala (sun's diurnal circle on Summer solstice day) and the outer limit of the outermost maṇḍala (sun's diurnal circle on Winter solstice day) ?

(The answer is) $510\frac{48}{61}$ Yojanas."

This shows that the average velocity of sun in the north-south direction across the solar maṇḍalas

$= 510$ Y/183 days

$= 2\frac{48}{61}$ Y/day

$\therefore$ The north-south stretch of a solar maṇḍala $= 2\frac{48}{61}$ Y

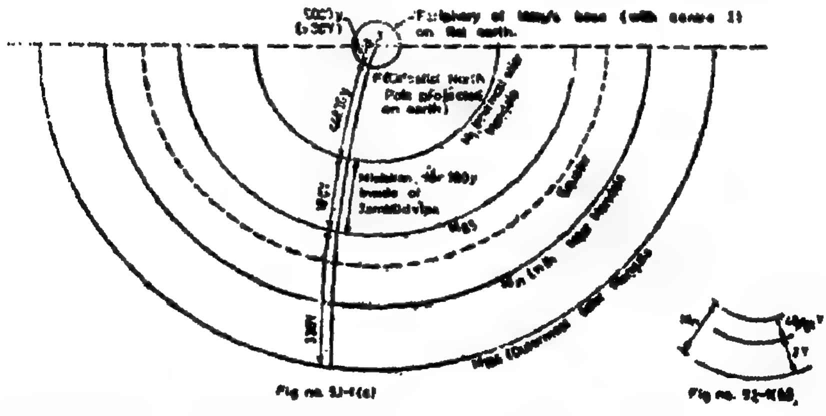


Fig. No. 5.1-1. *North-South angular stretches of solar Maṇḍalas (Diurnal circles), their distances from periphery of Meru's base on flat earth measured in linear measures along the surface of flat earth (N.B. however actual determinations fit the actual geometry of earth) as per jaina canonical texts.*

Now distance between two consecutive maṇḍalas = 2Y

$\therefore$ Thickness of a solar maṇḍala $= \frac{48}{61}$Y.

This alludes to the notion that a solar maṇḍa'a inherently implies a notion of the strap of diurnal path described by the solar disc. Thus the north-south breadth (as per Jaina canon being called as 'thickness' heretofore) of the strap of a solar maṇḍala is $\frac{48}{61}$Y. However the distance between the inner limit of the innermost maṇḍala (sun's diurnal path on Summer solstice day) and the outer limit of the outermost maṇḍala (sun's diurnal path on Winter solstice day) is $510\frac{48}{61}$ Yojanas.

Let M_n denote nth solar maṇḍala (sun's diurnal path) beginning from innermost solar maṇḍala where n is a natural number such that $1 \leqslant n \leqslant 184$. Thus

M_1 = innermost solar maṇḍala (sun's diurnal path on summer solstice day)

M_2 = Second to innermost solar maṇḍala

... ...

M_n = nth solar maṇḍala ... ...

... ...

M_{184} = Outermost solar maṇḍala (sun's diurnal path on Winter solstice day).

The whole pattern of solar maṇḍalas is shown in fig. No. (5.1-1).

Besides, diameters and circumferences of all the solar maṇḍalas (sun's diurnal paths) are also stated in SP. 1. 8 as (Quotation No. 5.1-5).

i.e. "When the sun treads upon the innermost maṇḍala (sun's diurnal circle on Summer solstice day) the maṇḍala has $\frac{48}{61}$ Yojanas thickness (north-south breadth of the starp of diurnal path described by the solar disc), 99640

yojanas diameter and a slight more than 315089 yojanas circumference.

...Second to the innermost maṇḍala, ... $\frac{48}{61}$ Yojanas thickness, $99645\frac{35}{61}$ yojanas diameter and a slightly less than 315107 yojanas circumference.

Likewise, treading upon maṇḍala to maṇḍala, when the sun moves on the outermost maṇḍala (sun's diurnal circle on Winter solstice day), the maṇḍala has $\frac{48}{61}$ Yojanas thickness, 100660 yojanas diameter and 318315 yojanas circumference."

The dimensions of solar maṇḍalas can be easily computed as follows :

$$\text{Radius} = \frac{\text{Diameter}}{2}$$

Or

$$R_{M_n} = \frac{D_{M_n}}{2} \qquad \ldots \quad \ldots \quad \ldots \quad \ldots \quad \ldots(5.1\text{-}11)$$

where R_{M_n} = Radius of M_n (nth solar maṇḍala or sun's duirnal path)

D_{M_n} = Diameter of M_n

Vide quot. No. (5.1-5), for the innermost solar maṇḍala M_1 we have

$$\begin{aligned} R_{M_1} &= \frac{99640}{2} = 49820 \text{ y} \\ &= 44820 \text{ y} + 5000 \text{ y} \\ &= \text{NPD of } M_1 + \text{Radius of Meru's base on flat earth} \end{aligned}$$

Analogically, we have

$$^{R}M_{n} = \text{NPD of } M_{n} + \text{Radius of Meru's base on flat earth}$$

Differentiating both sides with regard to time t, we have

$$\frac{d}{dt}\left(^{R}M_{n}\right) = \frac{d}{dt}(\text{NPD of } M_{n}) + 0 \ldots \quad \ldots \quad \ldots (5.1\text{-}12)$$

($\because$ Radius of Meru's base on flat earth remains constant).

Thus the rate of variation of radii of the solar maṇḍalas is in toto the same as the rate of variation of their north polar distances (NPD) from periphery of the mount Meru's base on flat earth.

So using equation No. (5.1-3),
we have from equation No. (5.1-12) that

$$\frac{d}{dt}\left(^{R}M_{n}\right) = 2\frac{48}{61} \text{ Y/day}$$ (day and night, the time taken by sun to traverse one solar maṇḍala).

Using eq. No. (5.1-11), we have

$$\frac{d}{dt}\left(^{D}M_{n}\right) = 5\frac{35}{61} \text{ Y/day} \ldots \quad \ldots \quad \ldots \quad \ldots (5.1\text{-}13)$$

i.e. diameters of the solar maṇḍalas vary as $5\frac{35}{61}$ Yojanas per day (day and night, the time taken by sun to traverse one solar maṇḍala or sun's diurnal circle).

The circumference of any solar maṇḍala has verily been computed in an alike manner as R. C. Gupta[4] has shown in his paper 'Circumference of Jambūdvīpa in Jaina Cosmography' that circumference of Jambūdvīpa (isle of Jambū tree) had been supputed from its diameter by using only approximate values of π. They had commonly employed the following formula

$$^{C}M_{n} = \sqrt{10\ D^{2}_{M_{n}}}$$

Or

$$^{C}M_{n} = \sqrt{10}\ ^{D}M_{n} \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad \ldots (5.1\text{-}14)$$

where $^{C}M_{n}$ = circumference of M_n (nth solar maṇḍala).

But they did not use the correct value of the square root of ten but in stread, for finding out the square root of a non-square positive number N, the following bionomial approximation was frequently used during the ancient and medieval times :

$$\sqrt{N} = \sqrt{(a^2 + x)} = a + \left(\frac{x}{2a}\right) \quad \ldots \quad \ldots \quad \ldots \quad \ldots (5.1\text{-}15)$$

Where a and x are positive integers and the remainder x is less than the divisor 2a ; otherwise or alternately, we may use

$$\sqrt{N} = \sqrt{(b^2 - y)} = b - \left(\frac{y}{2b}\right) \quad \ldots \quad \ldots \quad \ldots \quad \ldots (5.1\text{-}16)$$

The approximation (5.1-15) was known to the Greek Heron of Alexandria (between c. 50-c. 250 A.D.),[5] and even to the ancient Babylonians.[6] The Chinese Sun Tzu (between 280 and 473 A.D.)[7] while extracting the square root of 234567 by an elaborate method, finally said[8] :

"Thus we get 484 for the square root in the above and 968 for the hsia-fa, the remainder being 311."

Thus he gave the answer : $484 + \left(\frac{311}{968}\right)$ which is equivalent to what we get by using the eq. No. (5.1-15).

The Jaina Gem Dictionary[4] (pp. 154-155) gives the same rule as represented by the eq. No. (5.1-15). The TP. 1.117 (Vol. I)[9] implies that the circumference of a circle of diameter one yojana

was found out to be $\frac{19}{6}$ yojanas, which is in agreement with the use of the eq. No. (5.1-15), as we have

$$\sqrt{10} = \sqrt{(3^2 + 1)} = 3 + \left(\frac{1}{6}\right).$$

Likewise, using eq. No. (5.1-15) or alternately eq. No. (5.1-16) the given circumferences of the solar maṇḍalas can be easily generated. Exempli gratia, we may see that

$$C_{M_1} = \sqrt{10\, D^2_{M1}} = \sqrt{10 \times (99640)^2}$$

$$= \sqrt{(315090)^2 - 412100} \quad \text{using eq. No. (5.1-16)}$$

$$= 315090 - \frac{412100}{630180}$$

= Slightly more than 315089 y (given, see quot. No. 5.1-5).

Now a passing reference may be made about the distance between two suns always remaining diametrically opposite on both sides of Meru. In this context, SP. 1.4 states as :

(Quotation No. 5.1-6).

i.e. "When the two suns tread upon the innermost (solar) maṇḍala, they move 99640 yojanas apart from each other."

Here it is given that

distance between two suns moving on M_1 = 99640 y

= D_{M_1} (see quot. No. 5.1-5)

= Diameter of innermost solar maṇḍala

A similar treatment holds good in case of any other solar maṇḍala also. However this reveals the fact that the celestial angular distance between two suns was measured in yojanas in terms of its corresponding distance projected over the surface of earth. Jainas had such traditions as discussed earlier also (see 3.2).

5.2. KINEMATICS OF THE SUN

(a) *Spiral Motion of the Sun*

We know that a solar maṇḍala (sun's diurnal circle) is described in one day (day and night) (see eq. No. 5.1-2). Jainas had supposed two suns describing half diurnal circle each (see 3.1). The phenomenon can be explained on the basis of their motion in a plane with constant angular velocity. Semicircles are to be drawn for the paths of two suns with increasing radii. Either sun starts at one end of his own semicircular path and reaches the end of the next (consecutive) path in one ahorātra (day and night). This is pictured as depicted by L.C. Jain,[19] as a spiral with an equation which is skin to that of the Archimedian spiral, i.e.

$$r = a\,\theta \qquad \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots (5.2\text{-}1)$$

where r = radius, θ = argument, and a = constant.

The angular velocity remains constant and the linear velocity is accelerated (or retarded) every instant in sun's southern course (or northern course). In accordance with the theory of two suns, two similar spirals of this type are simultaneously traced such that distance between any two parallel points on them is equal to the distance between the two suns occupying those points at any instant during their annual course.

Now $\because\ \dot{\theta} = \omega$ = angular velocity = constant.
Suppose the radius at any instant = u

$\therefore$ from eq. No. (5.2-1), we have

$$u = a\,\theta \qquad \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots (5.2\text{-}2).$$

Differentiating eq. No. (5.2-2) with respect to time t, we have

$$\dot{u} = a\,\dot{\theta}$$
$$= a\,\omega$$

$\therefore$ Linear velocity $= u\,\dot{\theta}$

$$= u\,\omega$$
$$= u\,\dot{u} \div a \qquad \ldots \ldots \ldots \ldots \ldots \ldots (5.2\text{-}3)$$
$$(\because\ \dot{u} = a\,\omega)$$

The actual radius R from the centre of the flat earth is given by

$\pi D = 2\pi R$ i.e. $R = \frac{1}{2}D$, where D is the diameter of the mapped orbit of sun.

And R is also given by

$$R = \sqrt{u^2 + z^2}$$

Thus the co-ordinates for describing the position of sun are cylindrical, the origin being tentative centre of Meru's base on flat earth. But on Summer solstice day the tentative axis of Meru passes through a point lying on the periphery of 'samatala bhūmi' ('earth having plane surface' denoting circular area with centre at the projection of pole of ecliptic). One may be tempted to speculate that this very point might have been taken as origin and this notion might have been used to develop the concept of Citrā bhūmi (earth of Citrā or spica, probably denoting the horizontal plane of an observer having Citra (Spica) approximately at horizon). However still more investigations are to be made regarding the concept of Citrā bhūmi.

As regards the velocity of sun in various solar maṇḍalas, SP. 2.3 states as : (Quotation No. 5.1-1).

i.e "When the sun treads upon innermost maṇḍala (sun's diurnal circle on Summer solstice day), its velocity is $5251\frac{29}{60}$ yojanas per muhūrta (muhūrta = 48 minutes), ... upon the second to innermost maṇḍala, the velocity is $5251\frac{47}{60}$ yojanas per muhūrta, ... in this way, the sun moves from maṇḍala to maṇḍala, the velocity increases by $\frac{18}{60}$ yojanas per muhūrta (per maṇḍala), and the sun reaches the outermost maṇḍala (sun's diurnal circle on Winter solstice day) where its velocity is $5305\frac{15}{60}$ yojanas per muhūrta."

This is also explicity stated in JP. 7.6.

The velocity of sun occupying any particular solar maṇḍala can easily be generated as follows :

Diurnal path of two suns in M_n = C_{M_n} yojanas.

Either sun describes in M_n $= \frac{1}{2} C_{M_n}$ yojanas.

Let V_n = linear velocity of sun in M_n

By definition of the theory of diurnal motion of two suns i.e. two suns describe one solar maṇḍala a day (day and night) each describing one half, we have

$$v_n = \frac{1}{2} C_{M_n} \text{ yojanas/30 muhūrtas (One day and night)}$$

$$= \frac{1}{60} C_{M_n} \text{ yojanas/muhūrta} \quad \ldots \ldots \ldots \ldots \ldots (5.2\text{-}4)$$

Thus velocity of either sun in any solar maṇḍala (sun's diurnal circle) can conveniently be supputed from this equation. For instance, when the sun treads upon innermost solar maṇḍala (sun's diurnal circle on Summer solstice day) its velocity v_1 is given as

$$v_1 = \frac{1}{60} C_{M_1} \text{ yojanas/muhūrta}$$

But C_{M_1} = 315089 yojanas (See 5.1)

$$\therefore \quad v_1 = \frac{315089}{60} = 5251\frac{29}{60} \text{ yojanas/muhūrta}$$

= given (see quot. No. 5.2-1)

Besides, from eq. No. (5.2-4), we find

$$v_n = \frac{\sqrt{(10\, D^2_{M_n})}}{60} \quad (\because C_{M_n} = \sqrt{10\, D^2_{M_n}}$$

see eq. No. 5.1-14)

Differentiating with respect to time t, we have

$$\dot{v}_n = \frac{\sqrt{10}}{60} \dot{D}_{M_n}$$

Using eq. No. (5.1-13), i.e.

$$\dot{D}_{M_n} = \frac{d}{dt}(D_{M_n}) = 5\frac{35}{61} \text{ Y/day (day and night),}$$

We have

$$\dot{v}_n = \frac{1}{60} \cdot \frac{340\sqrt{10}}{61} \text{ yojanas/muhūrta/day}$$

Using eq. No. (5.1-16), we find

$$\left(\frac{340\sqrt{10}}{61}\right) = \sqrt{\left(\frac{1098}{61}\right)^2 - \frac{49604}{61^2}}$$

$$= 18 - \frac{49604}{61^2 \times 2 \times \frac{1098}{61}}$$

$$= 18 - \frac{49604}{133956}$$

$$= 18 \text{ approx.}$$

$$\therefore \dot{v}_n = \frac{18}{60} \text{ yojanas/muhūrta/day} \qquad \cdots \quad \cdots \quad \cdots \quad \cdots (5\ 2\text{-}5)$$

=given (see quot. No. 5.2-1)

Integrating eq. No. (5.2-5), we have

$$= \int_0^n \frac{18}{60}\, dt + c \qquad \text{where } c = \text{constant}$$

n = number of days counted from Summer solstice day or yet to go for that

applying initial conditions, *i.e.* when the sun treads upon the innermost maṇḍala M_1,

$$n = 1$$

$$v_1 = 5251\frac{29}{61} \text{ yojanas/muhūrta}$$

∴ The above equation becomes as

$$v_n = \int_0^n \frac{18}{60}\, dt + \left(5251\frac{29}{60} - \frac{18}{60}\right) \text{yojanas/muhūrta}$$

or

$$v_n = \frac{18}{60}(n-1) + 5251\frac{29}{60} \text{ yojanas/muhūrta} \quad \ldots \quad \ldots \quad \ldots (5.5\text{-}6)$$

(b) *Distances of Sun from the Man (Observer)*

The distances between the man (observer) and sun occupying different maṇḍalas (diurnal circles) are explicitly stated in SP.2.3 as :

(Quotation No. 5.2-2).

i.e. "When the sun moves on the innermost maṇḍala (sun's diurnal circle on Summer solstice day), its distance from the manuṣya (man) is $47263\frac{21}{60}$ yojanas, ...

second to the innermost maṇḍala,

$47179\frac{57}{60} + \left(\frac{1}{61} \times \frac{1}{61} \times \frac{19}{1}\right)$ yojanas; ... ...

third to the innermost maṇḍala,

$47096\frac{33}{60} + \left(\frac{1}{60} \times \frac{1}{61} \times \frac{2}{1}\right)$ yojanas

... the outermost maṇḍala (sun's diurnal circle on Winter solstic day), $31831\frac{30}{60}$ yojanas.

......second from the outermost maṇḍala,

$31916\frac{41}{60} + \left(\frac{1}{60} \times \frac{1}{61} \times \frac{6}{1}\right)$ yojanas;...

...third from the outermost maṇḍala,

$32001\frac{51}{60} + \left(\frac{1}{60} \times \frac{1}{61} \times \frac{31}{1}\right)$ yojanas."

These data are easily put in table (5.2-1).

TABLE 5.2-1

TABLE OF DISTANCES OF SUN FROM THE MAN (OBSERVER)

Serial Number of solar maṇḍala (M_n) *occupied by sun*	*Distance of sun from the man (observer),* d_n (*in yojanas*)	*First difference,* $\Delta d_n = d_{n+1} - d_n$	*Second difference* $\Delta' d_n = \Delta d_{n+1} - \Delta d_n$
M_1 (innermost)	$47263\frac{21}{60}$	$-83\frac{1445}{60\times61}$	$-\frac{36}{60\times61}$
M_2	$47179\frac{57}{60}+\left(\frac{1}{60}\times\frac{1}{61}\times\frac{19}{1}\right)$		
		$-83\frac{1481}{60\times61}$	
M_3	$47096\frac{33}{60}+\left(\frac{1}{60}\times\frac{1}{61}\times\frac{2}{1}\right)$		
M_{182}	$32001\frac{51}{60}+\left(\frac{1}{60}\times\frac{1}{61}\times\frac{31}{1}\right)$		
		$-85\frac{641}{60\times61}$	$-\frac{36}{60\times61}$
M_{183}	$31916\frac{41}{60}+\left(\frac{1}{60}\times\frac{1}{61}\times\frac{60}{1}\right)$		
		$-85\frac{677}{60\times61}$	
M_{184} (outermost)	$31831\frac{30}{60}$		

The rationale of computation of these distances is elucidated in the following paragraph :

Let

d_n=distance of the man (observer) from sun in M_n

v_n=average linear velocity of sun M_n

l_n=length of day when the sun treads upon M_n

and d'_n=angular distance traversed by sun along the circumference of M_n in a period from sunrise upto sun's transit of observer's meridian *i.e.* in half the length of daylinght.

Since according to dynamics of a particle, we know that

distance=average velocity × *time*

$$\therefore \; d'_n = v_n \times \frac{l_n}{2} \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad \ldots (5.2\text{-}7)$$

Now, for n=1, we have

$$v_1 = 5251\frac{29}{60} \text{ yojanas/muhūrta (see eq. No. 5.2-4)}$$

and l_1=18 muhūrtas (see 6. 3b)

∴ From eq. No (5.2-7), we have

$$d'_1 = 5251\frac{29}{60} \times \frac{18}{2} = 47263\frac{21}{60} \text{ yojanas}$$

$$= d_1 \text{ (see quot. No. 5.2-2)}$$

Similarly, for the outermost maṇḍala, n=184

$$v_{184} = 5305\frac{15}{60} \text{ yojanas/muhūrta (see 5.2, quot. No. 5.2-1 or see eq. No. 5.2-4)}$$

and l_{184}=12 muhūrtas (see 6.3b)

∴ From eq. No. (5 2-7), we have

$$d'_{184} = 5305\frac{15}{60} \times \frac{12}{2} = 31831\frac{30}{60} \text{ yojanas}$$

$$= d_{184} \text{ (see quot. No. 5.2-2)}$$

Similarly d_n can easily be computed from eq. No. (5.2-7) such that

$$d_n = d'_n = v_n \times \frac{l_n}{2} \quad \cdots \quad \cdots \quad \cdots \quad \cdots \quad \cdots (5.2\text{-}8)$$

Similarly, for (n+1)th solar maṇḍala, we have

$$d_{n+1} = v_{n+1} \times \frac{l_{n+1}}{2}$$

$$= \frac{(v_n + \Delta v_n)(l_n + \Delta l_n)}{2} \quad \cdots \quad \cdots \quad \cdots \quad \cdots (5.2\text{-}9)$$

Subracting eq. No. (5.2-8) from eq. No. (5.2-9), we have

$$\Delta d_n = d_{n+1} - d_n = \frac{v_n \Delta l_n + \Delta v_n l_n + \Delta v_n \Delta l_n}{2}$$

Now $\because$ $\Delta l_n = \frac{-2}{61}$ muhūrtas/day... ... ...(see 6.3b)

$$\Delta v_n = \frac{18}{60} \text{ yojanas/day} \quad \cdots \quad \cdots \cdots \cdots (\text{see eq. No. } 5.2\text{-}5)$$

$$v_n = \frac{18}{60}(n-1) + 5251\frac{29}{60} \quad \cdots \quad \cdots \quad \cdots (\text{see eq. No. } 5.2\text{-}6)$$

and $l_n = 18 - \frac{2}{60}(n-1)$ ... ...(see 6.3b)

$$\therefore \quad \Delta d_n = -\frac{36(n-1)}{60 \times 61} - 83\frac{1445}{60 \times 61} \quad \cdots \quad \cdots \quad \cdots (5.2\text{-}10)$$

$$\therefore \quad \Delta d_1 = -83\frac{1445}{60 \times 61}$$

$$\Delta d_2 = -83\frac{1481}{60 \times 61}$$

....

....

....

$$\Delta d_{189} = -85\frac{641}{60 \times 61}$$

$$\Delta d_{183} = -85\frac{677}{60 \times 61}$$

These value of d_n agree with the given data (see table 5.2-1)
Again from eq. No. (5.2-10), we have

$$\Delta d_{n+1} = -\frac{36n}{60 \times 61} - 83\frac{1445}{60 \times 61} \quad \ldots \quad \ldots \ldots \quad \ldots (5.2\text{-}11)$$

Substracting eq. No. (5.2-10) from eq. No. (5.2-11), we have

$$\Delta' d_n = \Delta d_{n+1} - \Delta d_n = -\frac{36}{60 \times 61} \text{ yojanas}$$

$$= \text{constant (given see table 5.2-1)}$$

when the sun occupies nth solar maṇḍala (diurnal circle),

v_n = Sun's mean velocity in yojanas per muhūrta (=48 minutes)

l_n = Length of daylight.

d_n' = Diurnal arc from sunrise to solar transit of observer's meridian.

$$= v_n \times \frac{l_n}{2}$$

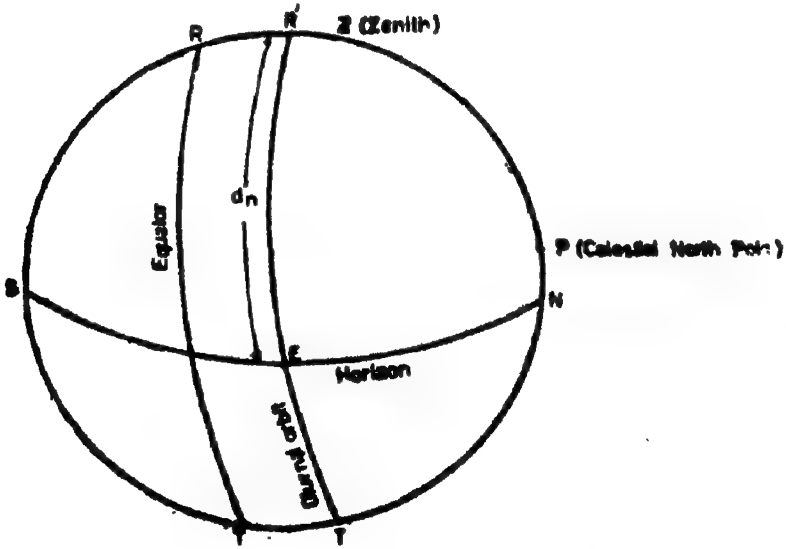


Fig. No. 5.2-1. *'Sun's distance from the observer' actually denoting sun's diurnal arc from sunrise to solar transit of observer's meridian.*

In our conclusory opinion, it is verisimilar that the angular distance d'_n the sun is supposed to traverve along the circumference of the of nth solar maṇḍala M_n in a period from sunrise (beginning of sun's journey on M_n) upto sun's transit of observer's meridian (local mean noon), (see fig. No. 5.2-1) has been implicity stated to be d_n *i.e.* the distance between the man (observer) and sun while occupying M_n. Thus the distance of the observer from sun at the time of local mean moon (meridian transit of sun) is zero according to this exposition. This reflects upon their inclination towards the measurement of noon-shadow-length. Moreover it lends support to the fact that celestial distances were measured in terms of corresponding distances projected over the surface of earth. Probably the same tradition had continued down to the period of advent of Sidhāntic astronomy because it is clearly explained in Pañcasiddhāntikā[12] (xii.15) that the longitudinal difference between two places *i e.* the angular distance in degrees was measared into yojanas on the surface of the earth whose circumference was assumed to be 3200 yojans.

Thus it is convincing to conclude that the distance d_n should not be confused with vertical height of sun while occupying *n*th solar maṇḍala M_n. Besides, it is worth mentioning here that, in second/third century B.C, solar perigee occurred in Uttarāṣāḍhā (σ Sagittarii). The Winter solstice occurred in Abhijit (α Lyrae). As it is evident from table (5.2-1), distance of the man (observer) from sun while treading upon the outermost maṇḍala (sun's diurnal circle on Winter solstice day) is minimum. It creates an illusion as if the distance d_{184} of the man from sun occupying the outermost solar maṇḍala (sun's diurnal circle on Winter solstice day) (see table 5.2-1) implies a notion of solar perigee. One may be tempted to reveal any notion of elliptical motion of sun from these data.[13] But it is only a matter of chance that the solar perigee occurred near Winter solstice. In reality it appears that Jainas had no notion of elliptical motion of sun and we have exposed in a befitting manner how these figures could have been generated.

5.3 *LUNAR MAṆḌALAS (MOON'S DIURNAL CIRCLES)*

It is fascinating to note that the theory of solar maṇḍalas (sun's dirunal circles) exercised a staunch impact upon the emergence of

the parallel theory of lunar maṇḍalas (lunar dirnal circles). Such an exordial note to the conclusiveness of the theory of lunar maṇḍalas renders it more undeplorable and easily graspable. Besides, some short-cut methods have been put in practice in order to avoid unnecessary repitition of mathematical logic for exposing the rationale of some aspects of theory of lunar maṇḍalas parallel to those of theory of solar maṇḍalas. Due emphasis has been laid upon the newness of lunar maṇḍala theory in particular.

(a) *Number of Lunar Maṇḍalas (Lunar Diurnal Circles)*

There are fifteen lunar maṇḍalas. In this context, JP.7.17 states as : (Quotation No. 5.3-1).

i.e. "There are five lunar maṇḍalas (diurnal circles stretched over 180 Yojanas in Jambūdvīpa (isle of Jamū tree). There are ten lunar maṇḍalas stretched over 330 Yojanas of the Lavaṇasamudra (salt ocean). Thus in both Jambūdvīpa (isle of Jambū tree) and the Lavaṇasamudra (salt ocean) there are fifteen lunar maṇḍalas (lunar diurnal circles) in all."

The total north-south stretch across the lunar maṇḍalas

$$=180+330=510 \text{ Y.}$$

(b) *Linkage of lunar Maṇḍalas with Moon's Sidereal course among the Star*

Like the theory of two suns, two moons were considered to rise alternatively in southern quarter of Jambūdvīpa (isle of Jambū tree). As regards their motion in different lunai maṇḍalas, SP. 81 (Gaṇitānuyoga pp. 284-286 stated as : (Quotation No. 5.3-2).

i.e. "There are seven half-maṇdalas, viz. second, fourth, sixth, eighth, tenth, twelfth and fourteenth, in which moon moves at the time of enterning into the southern part (of Jambūdvīpa or isle of Jambū tree).

There are $6\frac{13}{67}$ half-maṇdalas, viz. third, seventh, ninth, eleventh, thirteenth, and $\frac{13}{67}$th part of fifteenth (lunar maṇ-

ḍala) in which moon moves at the time of entering into the northern part (of Jambūdvīpa).

In this way, the first candrāyana (moon's southern course among the stars) is over."

Thus the same moon moves on 7 plus $6\frac{13}{67}$ *i.e.* $13\frac{13}{67}$ half-maṇḍalas in candrāyana (half the sideral revolution of moon). According to Jaina theory of two suns and two moons etc, the counter-moon also moves on $13\frac{13}{67}$ half-maṇḍalas at the same time.

The total number of lunar maṇḍalas in one candrāyana (half the sidereal revolution of moon) = $13\frac{13}{67}$.

We know that a quinquennial yuga (cycle) contains sixty-seven nakṣatra months (lunar sidereal revolutions) or 134 candrāyanas.[11]

∴ Total number of lunar maṇḍalas in a five-year cycle.

$= 13\frac{13}{67} \times 134 = 1768$

= The number of lunar sāvaṇa days (moon-rises to moon-rises) in a five-year cycle.

This indicates that the total number of lunar maṇḍalas (lunar diurnal circles) in a five-year cycle has a one-one correspondence with the total number of sāvaṇa days (a sāvaṇa day means the period f-om moon-rise to moon-rise) in the same period (five-year cycle). Thus a lunar maṇḍala (lunar diurnal circle) is traversed in a lunar sāvaṇa day (moon-rise to moon-rise).

∴ Velocity of moon = 1 lunar maṇḍala/lunar sāvaṇa day ... ...(5.3-1)

Besides, it seem plausible that analogus to $\frac{13}{67}$th part of the fifteenth lunar maṇḍala (outermost lunar maṇḍala), there must exist only the $\frac{13}{67}$th part of the first lunar maṇḍala (innermost unar maṇḍala) upon which the moon traverses its path in the

northern part of Jambūdvīpa at about the ending moments of second-candrāyana (moon's sidereal northern course) such that it again starts its southern journey while entering into the southern part of Jambūdvīpa as before. It is intended to impress upon here that there are fifteen straps of lunar maṇḍalas (lunar diurnal circles) and fourteen spaces enclosed there between. Thus the moon during its sidereal revolution moves twice upon thirteen lunar maṇḍalas and only once upon $\frac{13}{67}$th part of each of the extreme lunar maṇḍalas viz. the first and the fifteenth.

(c) *Dimensions of Lunar Maṇḍalas*

As regards the dimensions of lunar maṇḍalas, JP.7.21 states as : (Quotation No. 5 3-3)

i.e. "What are the diameter and circumference of the innermost (lunar) maṇḍala (lunar diurnal circle corresponding to moon's extreme northern position).

(The answer is) 99640 yojanas diameter and slightly more than 315089 yojanas circumference.

What about second to the innermost maṇḍala ?

$99712\frac{51}{61} + \left(\frac{1}{61} \times \frac{1}{7}\right)$ yojanas diameter and slightly more than 315319 yojanas circumference.

What about third to the innermost maṇḍala ?

$99785\frac{41}{61} + \left(\frac{1}{61} \times \frac{1}{7} \times \frac{2}{1}\right)$ yojanas diameter and slightly more than 315549 yojanas circumference.

So likewise when the moon goes on advancing, the diameter goes on increasing by $72\frac{51}{61} + \left(\frac{1}{61} \times \frac{1}{7}\right)$ Yojanas per maṇḍalas and the circumference increases by 230 yojanas per maṇḍala.

What about the outermost (lunar) maṇḍala (lunar diurnal circle corresponding to moon's extreme southern position).

100660 yojanas diameter and 318315 yojanas circumference."

One may find at first sight that dimensions (diameter and circumference only) of the extreme lunar maṇḍalas (innermost lunar maṇḍala and outermost lunar maṇḍala) are exactly the same as those of the corrosponding extreme solar maṇḍalas (innermost solar maṇḍala and outermost solar maṇḍala) (see quot. No. 5.1-5, 5.1). Therefore distances of the extreme lunar maṇḍalas from periphery of Meru's base on flat earth are also the same as those of the corresponding extreme solar maṇḍalas. The dimensions (diameter, circumference, NPD from Meru) of lunar maṇḍalas other than extreme ones are generated alike to the computation of those of the similar (other than extreme ones) solar maṇḍalas. However it is to be noted that according to quot. No. (5 3-3) we have

Rate of change of diameter of lunar maṇḍalas

$= 72\frac{51}{61} + \left(\frac{1}{61} \times \frac{1}{7}\right)$ Yojanas/lunar sāvaṇa day (time taken by moon to traverse one lunar maṇḍala).

$\therefore$ Rate of change of radius of lunar maṇḍalas

$$= \tfrac{1}{2}\left\{ 72\frac{51}{61} + \left(\frac{1}{61} \times \frac{1}{7}\right)\right\} \text{ Yojanas/lunar sāvaṇa day} \qquad \ldots\ \ldots\ \ldots\ \ldots\ \ldots(5.3\text{-}2)$$

Since the radius increases fourteen times (corresponding to fourteen spaces between extreme lunar maṇḍalas) till the moon occupies fifteenth lunar maṇḍala in its southern journey and vice versa; so total change (increase or decrease) of radii of lunar maṇḍalas.

$$=14 \times \tfrac{1}{2}\left\{ 72\frac{51}{61} + \left(\frac{1}{61} \times \frac{1}{7}\right)\right\} \text{ Yojanas (using eq. No. 5.3-2)}$$

$$= 509\frac{53}{61} \text{ Yojanas} \qquad \ldots\ \ldots\ \ldots\ -\ \ldots(5.3\text{-}3)$$

$\therefore$ The distance between outer limit of innermost lunar maṇḍala and outer limit of outermost lunar maṇḍala is $509\frac{53}{61}$ Yojanas.

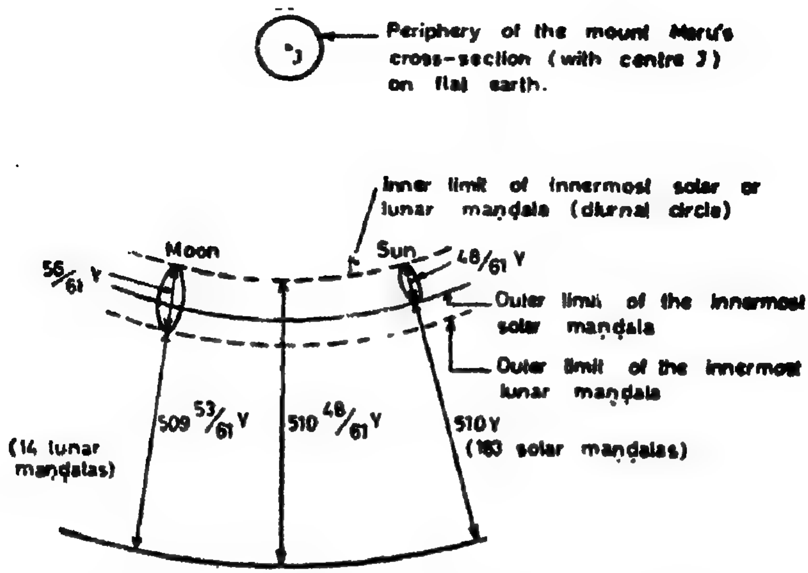


Fig. No. 5.3-1. *North-south angular distances (projected over surface of earth) between extreme solar and lunar maṇḍalas (diurnal circles) repectively as implied in jaina canonical texts. (N.B. This exposition relates to a situation prior to the development of notion of celestial latitude of moon).*

Bessides, as regards the thickness of every lunar maṇḍala, JP.7.19. states as : (Quotation No. 5.3-4).

i.e. "What are the diameter, circumference and thickness of a lunar maṇḍala ?

Every lunar maṇḍala is of $\frac{56}{61}$ Yojanas diameter, a little more than three times it circumference and $\frac{28}{61}$ Yojanas thickness."

In fact, these dimensions of every lunar maṇḍala appear to be dimensions of the lunar disc. Like the fact that north south breadth of strap of diurnal path of sun in any solar maṇḍala was equivalent to the diameter of the solar disc (see 5.1.d), analogically we may take that diameter of the lunar disc *i.e.* $\frac{56}{61}$ Yojanas deno-

ted the north-south breadth of strap of the lunar path. Therefore the distance between the outer limit of outermost lunar maṇḍala and the inner limit of innermost lunar maṇḍala is the sum of $509\frac{53}{61}$ Yojanas and the breadth of starp of innermost lunar maṇḍala $\left(\frac{56}{61}\text{ Yojanas}\right)$ and it is equel to $510\frac{48}{61}$ Yojanas. Thus the extremities of the extreme lunar maṇḍalas (outer limit of outermost lunar maṇḍala and inner limit of innermost lunar maṇḍala) are in toto coincident with the corresponding extremities of the corresponding extreme solar maṇḍalas (see fig. No. 5.3-1).

In the light of this discussion, it may be contemplated that lunar maṇḍala theory has been developed on the guidelines of solar maṇḍala theory. The notion of declination is equally implied in the concept of lunar maṇḍala (diurnal circle of moon).

5.4. *KINEMATICS OF THE MOON*

(a) *Spiral Motion of the Moon*

The kinematical studies of moon followed the course of developments parallel to that of kinematical studies of sun. The path of lunar disc treading upon several lunar maṇḍalas is also represented as a spiral whose equation is akin to that of the Archimedian spiral as already expounded in case of kinematical studies of sun (see 5.2). So the redecraft of theory of spiral motion of sun and moon needs not be reinforced here.

(b) *Distances of Moon from the Man (Observer)*

As regards distances between the man (observer) and moon treading upon several lunar maṇḍalas, JP.7.22 states as : (Quotation No. 5-4-1).

i.e. "When the moon moves upon the innermost maṇḍala,"

how much distance is covered in one muhūrta ?

(The moon) moves $5073\frac{7744}{13725}$ yojanas (per muhūrta).

At that time, the moon is seen at a distance of

$46263\frac{21}{60}$ yojanas from the man (observer).

Second to the innermost maṇḍala... ... ...

$5077\ \frac{3974}{13725}$ yojanas (per muhūrta).

Third to the innermost maṇḍala... ... ...

$5080\ \frac{13319}{13725}$ yojanas (per muhūrta).

Likewise, by increasing the velocity (of moon) at the rate of $3\frac{9625}{13725}$ yojanas per muhūrta, the moon reaches the outermost maṇḍala.

... ... the outermost maṇḍala, ... $5125\frac{6990}{13725}$ yojanas (per mahūrta). At that time, the moon is seen at a distance of 31831 yojanas from the man (observer)."

Firstly, it may be easily deemed that the linear velocity of moon along the circumference of any maṇḍala can verily be computed in a manner analogus to that which has been used in discerning the alike motion of sun (see 5.2a).

So analogus to eq. No. (5.2-4), we have linear velocity of moon in nth lunar maṇḍala

$$= \frac{1}{2}\,\frac{\text{circumference of nth lunar maṇḍala}}{\text{length of a lunar sāvaṇa day}}\ \text{yojanas/muhūrta}$$

$$= \frac{1}{2}\,\frac{\text{circumference etc.}}{\frac{13725}{442}}\ \text{yojanas/muhūrta}$$

($\because$ 1768 lunar sāvaṇa days $=$ 1 five-year-cycle

$=$ 1830 days of 30 muhūrtas each[21]

$$\therefore\ 1\ \text{lunar sāvaṇa day} = \frac{1830\times 30}{1768}\ \text{muhūrtas} = \frac{13725}{442}\ \text{muhūrtas})$$

$$= \frac{221}{13725}\times\text{circumference etc.} \qquad \ldots \qquad \ldots \qquad \ldots(5.4\text{-}1)$$

For instance, at the innermost lunar maṅdala,

$$\text{linear velocity of moon} = \frac{221}{13725} \times 315089$$

(∵ circumference of the innermost lunar maṇḍala

$$= 315089 \text{ yojanas})$$

$$= 5073\frac{7744}{13725} \text{ yojanas/muhūrta...}$$

Likewise, linear velocity of moon in any other given lunar maṇḍala can easily be computed by using eq. No. (5.4·1).

Now it is a matter of great concern that the distances between the man (observer) and moon have been given in two cases only, *i.e.* while the moon treads upon the innermost lunar maṇḍala and the outermost lunar maṇḍala respectively.

Several inferences from these data may be had as follows :

1. Analogus to the method of computation of man's distance from sun (half the diurnal arc of daylight) while occupying, as a particular case, the innermost solar maṇḍala, man's distance from moon (half the diurnal are of moonlight) while occupying the innermost lunar maṇḍala should have been calculated as follows :

Distance of man from moon=linear velocity of moon × half the length of time for which the moon remains actualy visible while treading upon innermost lunar maṇḍala.

But because the lengh of synodic period of moon is altogether different from its sideral period, so period of moolight while the moon treads upon the innermost lunar maṇḍala after every sidereal revolution is variable. The day of moon's motion upon the innermost lunar maṇḍala (lunar diurnal circle corresponding to moon's maximum north declination) can happen to be any lunar-day ranging from new moon day to full moon day. An alike logic holds good in case of any other lunar maṇḍala also. Therfore they were baffled with the ambiguity that arises on attempting to find the distance of man from moon as in case of sun. Then their

attention might have been called upon the fact, according to their theory solar and lunar maṇḍalas, that only the extreme lunar maṇḍalas were coincident with corresponding extreme solar maṇḍalas respectively. Consequently Jainas were led to perceive erroneously that the respective distances of man from moon and sun were the same when sun and moon occupied either of their common maṇḍalas *i.e.* the innermost and outermost. Evidently they left out the intricate problem of finding out the distances of man from moon while occupying lunar maṇḍalas other than the extreme ones.

2 The fact that the respective distances of man from moon and sun while occupying either of their common maṇḍalas (the innermost and the outermost) are one and the same, leads us to conclude that this concept of distance between the man and moon or sun does not imply any notion of vertical height of moon or sun Thus it seems plausible that such distances between the man and sun (see 5.2) denote on diffrent days of the year the celestial angular distances between the rising sun and sun's transit of obseverer's meridian in terms of corresponding linear distances projected over surface of the earth.

5.5 JAINIAN TRENDS TOWARDS NOTION OF HOUR ANGLE

In the light of foregoing discussions, now it would be worthwhile to revert to the criterion of uniform motion of sun along the circumfrence of the solar maṇḍala occupied by sun on any particular day. As solar maṇḍala theory is the forerunner of lunar maṇḍala theory, so our treatment in the present case will be restricted to it; the best reason for it will become evident in due time. The circumference of the particular solar maṇḍala superimposes upon the parallel of declination in modern terms.

In fig. No. (5.5-1), let

NS = horizon of the observer

Z = zenith

P = pole of equator

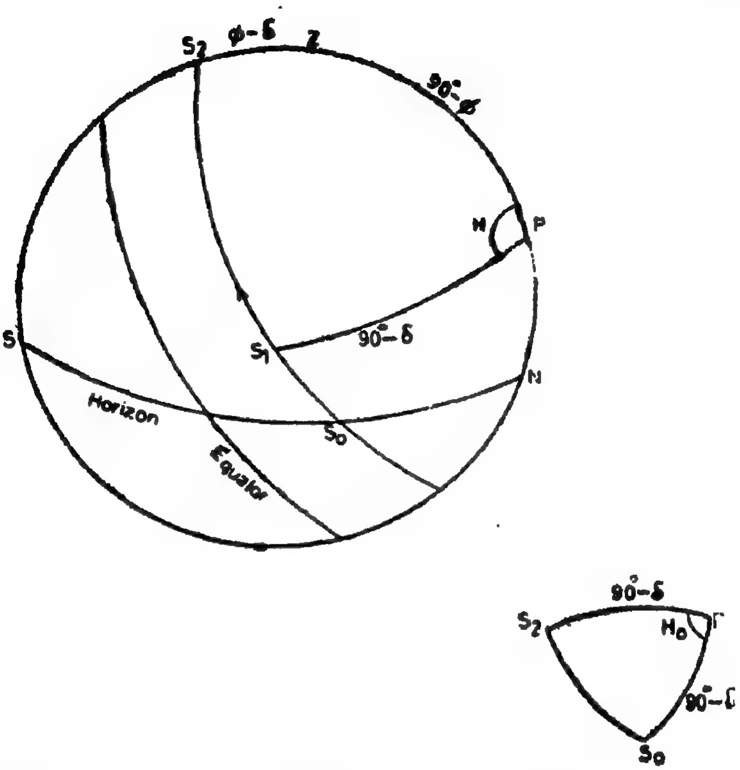


Fig. No. 5 5·1. *Notion of hour angle H implied in the concept of 'distance of the man from sun' S_0, S_2 (angular distance traversed by sun aalong its diurnal circle in a period from sunrise upto sun's transit of observer's meridian).*

S_0 S_2 = half the diurnal arc of daylight
ϕ = latitude of observer
δ = declination of sun
H = hour angle of sun posited at S_1
H_0 = hour angle of rising sun

Now from the spherical triangle S_1 P S_2, on using cosine formula* we have

$$\cos S_1 S_2 = \cos PS_1 \cos PS_2 + \sin PS_1 \sin PS_2 \cos S_1 PS_2$$
$$= \cos(90-\delta)\ \cos(90-\delta) + \sin\ (90-\delta)\ \sin(90-\delta)\ \cos H$$

$$= \sin^2 \delta + \cos^2 \delta \cos H$$

$$= 1 - \cos^2 \delta \, (1 - \cos H)$$

$\therefore$ $1 - \cos S_1 S_2 = \cos^2 \delta \, (1 - \cos H)$ ... ...(5.5-1)

$2 \text{ hav } S_1S_2 = 2 \cos^2 \delta \text{ hav } H$

or $\text{hav } S_1 S_2 = \cos^2 \delta \text{ hav } H$ ... ...(5.5-2)

$\because$ for a particular maṇḍala (sun's diurnal circle),
δ=constant approximately.

$\therefore$ $\text{hav } S_1S_2 \propto \text{hav } H$ ... ...(5.5-3)
whereas the constant of proportionality is $\cos^2 \delta$ and it remains constan t for a given solar maṇḍala.

However at the time of sunrise (see fig. No. 5.5-1.b),
$\text{hav } S_o\, S_3 \propto \text{hav } H_o$ ... ...(5.5.-4)

In particular, when $\delta=0$, from eq. No. (5.5-2), we have
$\text{hav } S_1\, S_2 = \text{hav } H$

$\therefore$ $S_1\, S_2 = H$

This suggests that Jaina might have endeavoured to measure hour angle of sun by measuring sun's course along the circumference of the solar maṇḍala occupied by sun on a particular day. But for $\delta \neq 0$, relation (5.5-2) does not reduee to any simple from. However at the time of sunrise (see eq. No. 5.5-5), attempts to measure $S_o\, S_3$ (half the diurnal arc of daylight or distance of the man, as per Jaina canonical texts, from sun occupying a particular maṇḍala) imply Jainian trends, albeit inadequately, towards the notion of hour angle H_o at the time of sunrise in a particular maṇḍala It is however an empirical relation and in the absence of an accurate knowledge about variation in sun's declination Jainas could not further develop their notion of hour angle by measuring distances (as implied in this context) between the man and sun at different instants of day. It seems quite plausible that Jainas had considered the motion of sun along the circumference of its maṇḍala, to be uniform only in context of their notion of hour angle as elucidated hereinfore, whereas they were aware of the ever increasing velocity of sun as per their notion of its spiral motion as elucidated earlier (see 5 2).

CHAPTER VI

The Jaina Calendar

The word 'calendar' was coined from the latin 'Kalendarium,' a list of interest payments due upon the first days of the months, the kalendae It was not used in its present sense by the early Romans who used 'Fasti' to indicate a list of days in which the holidays were designated.[1] The calendar is however defined as an arrangement of days in larger groups for the pupose of arriving at a chronological system as comformable as possible with nature.[2] There were many kinds of calendars current in different parts of the world and diversity of calendars has not as yet ended for common use of the world. The calendar has a long history. In this section, a simple probe is rendered into the several characteristics of the various parts of Jaina calendar, viz. samvatsara (year), month, day, tithi (lunar-day), karaṇa (half-lunar-day), yoga (combination) and nakṣatra (asterism).

6.1 *SAMVATSARA (YEAR)*

Samvatsara means an year. There are five kinds of samvat saras (years). SP.10.20.1 states : (Quotation No. 6.1-1).

i.e. "There are five (kinds of) samvatsaras (years), viz. nakṣatra (asterism) samvatsara, yuga (cycle) samvatsara, pramāṇa (authentic) samvatsara, lakṣaṇa (symptomatic) samvatsara (and) sanicchara (saturn) samvatsara."

This also explicitly stated in JP.8.

The various samvatsaras (years) are described as under :

1. NAKṢATRA SAMVATSARA (Asterism Year)

Nakṣtra samvatsara (asterism year) is defined as the length of twelve nakṣatra months (sidereal revolutions of moon). As we know that moon completes sixty-seven sidereal revolutions in a five-year cycle of 1830 days[3] *i.e.*

67 lunar sidereal revolutions $= 1830$ days

or 1 lunar sidereal revolution $= 27\frac{21}{67}$ days

$\therefore$ 1 nakṣatra samvatsara $= 327\frac{51}{67}$ days ... ...(6.1-1)

(asterism year)

There are twelve kinds of nakṣatra samvatsaras (asterism years). In this contest, SP. 10. 20. 2 states: (Quotation No. 6.1-2).

i.e. There are twelve (kinds of nakṣatra samvatsaras) viz. sāvaṇa, bhādrapada etc. upto aṣāḍha. Jupiter completes one revolution among the stars in twelve nakṣatra samvatsaras."

This indicates that the twelve-year cycle of nakṣatra samvatsaras (asterism years) was linked with the sidereal motion of jupiter. Accordingly,

1 sidereal revolution of jupiter $= 12$ nakṣatara samvatsaras

$= 3933\frac{9}{67}$ days ... ...(6.1-2)

(using eq. No. 6.1-1)

Besides, the five-year cycle begins with moon's entry into Abhijit (α Lyrae) nakṣatra (asterism) and moon reoccupies the same position after the completion of twelve sidereal revolutions ($\frac{1}{12}$th sidereal revolution of jupiter) or at the beginning of thirteenth sidereal revolution. And zero of zodiacal circumference also coincided with the beginning of Abhijit (α Lyrae) nakṣatra (asterism), so probably jupiter also, as N. C. Shastri[39] also opines, started its sidereal motion with its entry into Abhijit (α Lyrae) nakṣatra (asterism). Thus nakṣatra samvatsara (asterism year) was probably called after the name of nakṣatra (asterism) occupied by jupiter at the time of completion of twelfth sidereal revolution of moon or the beginning of thirteenth sidereal revolution of moon *i.e.* the beginning of another nakṣatra samvatsara. Thus the first nakṣatra samvatsara (asterism year) was called 'sāvaṇa' corresponding to jupiter's position in Śravaṇa (αAquilae) nakṣatra (asterism) or its neighbourhood *i.e.* the zodiacal intercept consisting of Abhijit (α Lyrae), Śravaṇa

(α Aquilae) and Dhaniṣṭhā (β Delphini) nakṣatras (asterisms). Thus The zodiacal circle was divided into twelve such intercepts and a lunar month was also called after the name of a nakṣatra (asterism) belonging to a particular zodiacal intercept where moon is posited on pūrṇimā (full moon day) (for details see 6.8 and table 6.8-1). Thus the beginning of twelve-year cycle of nakṣatra samvatsaras (asterism-years) may not strictly be marked with jupiter's conjuction with moon at the beginning of Abhijit (α Lyrae) nakṣatra (asterism) but instead jupiter may conveniently be considered as posited in the zodiacal intercept containing Śravaṇa (α Aquilae) nakṣatra (asterism). Ergo it suggests that Jainas had made empirical studies of kinematics of jupiter. This is also evident from the fact that the modern value of sidereal period of jupiter is 4332.589 days[5] which compared with the value given by eq. No. (6.1-2) gives an error of about 399 days (=4332.589 − 3933.134). It is contemplable that when jupiter went out of phase with its compatibility with the twelve-year cycle of nakṣatra samvatsaras (asterism years) Jainas might have been tempted to devise a better cycle like the sixty-year cycle of Bārhaspatya varṣas (jupiterian years) popularly known as Jovian years. Using equation No. (6 1-2), it may easily be seen that,

60 nakṣatra samvatsaras $= 19665\frac{45}{67}$ days $= 19665.672$ days

4 sidereal revolutions of jupiter[5] $= 17330.356$ days

Difference $= 2335.316$ days

= 7 nakṣatra samvatsaras (asterism years) and 40.989 days (see eq. No. 6.1-1).

Therefore, the sixty-year-cycle (of nakṣatra samvatsaras) may empirically be considered compatible with four sidereal revolutions of jupiter provided seven nakṣatra samvatsaras (asterism years) are decayed. This suggests that the sixty-year-cycle was probably originated as a hyarid of twelve-year-cycle of nakṣatra samvatsaras (asterism years) and the five-year-yuga (cylce) of Jyotiṣa Vedāṅgam which remained in vogue during the period of Jaina astronomy

also. Later the sixty-year-cylce comprised of lunar samvatsaras (years) instead of nakṣatra samvatsaras (asterism years), because it has better synchronization with the sidereal motion of jupiter. It may easily be seen that

1 lunar samvatsara (year)[39] $= 354\frac{12}{62}$ days $= 354.193$ days

but 5 lunar samvatsaras[39]	=1830 days (*i.e.* a five-yer-cyle)
∴ 60 lunar savatsaras	=21960 days
5 sidereal revolutions of jupiter[3]	=21662.945 days
Difference	=297.055 days
	=354 193−57.138 days
	=1 lunar samvatsara (year)— 2 lunar months.

So if one lunar samvatsara be decayed and two lunar months be intercalated instead, the sixty-year-cycle of lunar samvatsara (years) becomes highly compatible with a period of five sidereal revolutions of jupiter.

It may be mentioned here that beginning of the sixty-year-cycle of Jovian years occurs while jupiter enters into an Indian sign by mean motion; the first, thirteenth, twenty-fifth, thirty-seventh and forty-ninth years being determined by the entry of jupiter into the sign Kumbha (Aquarius) and not Meṣa (Aries) which is otherwise the first of the signs of the Siddhāntic texts. This suggests that the system of counting Jovian years is a pre-Siddhāntic practice.[4] Besides, the Indian sign Kumbha (Aquarius) commences from the middle of Dhaniṣṭhā (βDelphini) nakṣatra (asterism) which belongs to the zodiacal intercept comprising of Abhjit (α Lyrae), Śravaṇa (α Aquilae) and Dhaniṣṭhā (β Delphini) (see 6.8 and table 6.8-1). So it is quite probable that the sixty-year-cycle (hybrid of twelve-year cycle of nakṣatra samvatsaras and five-year-cycle) originated when Dhaniṣṭhā (β Delphini) headed the list of nakṣatras (asterisms) and Winter solstice occurred at the middle of Dhaniṣṭhā (β Delphini); and jupiter's position in the middle of Dhaniṣṭhā was still held in esteem in spite of the fact that Winter solstice had receded to the beginning of Abhijit (α Lyrae) and nakṣatra samvatsaras (asterism years) were replaced by lunar samvatsaras in the

sixty-year-cycle. Thus the present day association of jupiter's position in the Indian sign Kumbha (Aquarius) should not be misleading towards later origin of the practice of sixty-year-cycle. Rather it may be contemplated that the concept of twelve-year-cycle of nakṣatra samvatsaras may belong to the period when Winter solstice occurred in the middle of Dhaniṣṭhā (β Delphini) which subsequently led to the emergence of the concept of sixty-year-cycle of nakṣatra samvatsaras (asterism years). The sixty-year-cycle of Jovian years may be reproduced as follows :[3]

TABLE 6.1-1

NAMES OF THE JOVIAN YEARS

S. No.	*Name*	*S. No.*	*Name*	*S. No.*	*Name*
1.	Prabhava	21.	Sarvajitu	41.	Plavaṅga
2.	Vibhava	22.	Sarvadhāri	42.	Kīlaka
3.	Śukla	23.	Virodhi	43.	Saumya
4.	Pramodita	24.	Vikṛti	44.	Sādhāraṇa
5.	Prajotpati	25.	Khara	45.	Virodhiṛtu
6.	Agīrasa	26.	Nandana	46.	Paridhātu
7.	Śrimukha	27.	Vijaya	47.	Pramādita
8.	Bhāva	28.	Jaya	48.	Ānanda
9.	Yuva	29.	Manmatha	49.	Rākṣasa
10.	Dhātu	30.	Durmukhi	50.	Nala
11.	Īśvara	31.	Hevilanbi	51.	Piṅglā
12.	Bahudhānya	32.	Vilanvi	52.	Kālayukti
13.	Pramāthi	33.	Vikāri	53.	Sidhārthi
14.	Vikrama	34.	Śavitri	54.	Raudri
15.	Vṛṣa	35.	Plava	55.	Durmati
16.	Citrabhānu	36.	Śubhakṛtu	56.	Dundubhi
17.	Subhānu	37.	Śobhanakṛtu	57.	Rudhirodgāri
18	Tāraṇa	38.	Krodhi	58.	Raktākṣi
19.	Pārthiva	39.	Viśvāvasu	59.	Krodhana
20.	Vyaya	40.	Prābhava	60.	Kṣaya

Besides, regarding the rationale of sixty-year-cycle, S.R. Das[30] opines that since

A five-year-cycle = 60 solar months
= 61 ṛtu (seasonal) months
= 62 lunar months
= 67 nakṣatra months

So lunar year (consisting of twelve lunar months) and solar year (consisting of twelve solar months) commence at the same point or day and also close simultaneously once in every thirty years (six cycles of five years each), for the lunar year gains 6×2 i.e. 12 lunar months and thus an intercalary lunar year is completed. Similarly, the solar, ṛtu (seasonal), lunar and nakṣatra years simultaneously begin and close once in every twelve cycles of five years each i.e. sixty years. Likewise we have from above that

12 five-year-cycles = 60 solar years
= 61 ṛtu (seasonal) years
= 62 lunar years
= 67 nakṣatra years

Perhaps such type of an approach might have played some role in the emergence of sixty-year-cycle but this idea seems not to be substantially acceptable because the sixty-year-cycle of Jovian years is tout a fait associated with kinematical studies of jupiter.

It is worthy of note that sixty-year-cycle of Jovian years is still used by Indian almanac-makers and it influences several liturgical performances of Hindus.

2. YUGA SAMVATSARA (Period Year)

In the context of Jaina astronomical system, 'yuga' (a long mundane period of years) refers to a five-year-cycle of Jaina luni-solar fixed calendar. Thus yuga samvatsara denotes a lunar year belonging to the quinquennial cycle. There are five yuga samvatsaras. In this context, SP. 10.20.3 states : (Quotation No. 6.1-3)

i.e. "There are five kinds of yuga samvatsaras (period years) viz. lunar, lunar, abhivardhana ('lustfully increased' year denoting lunar year with an intercalary lunar month), lunar (and) abhivardhana.

First lunar samvatsara (year) contains twenty-four parvas (parva means one half of a lunar month). Second lunar samvast-

sara contains twenty-four parvas. Third abhivardhana samvatsara contains twenty-six parvas. Fourth lunar samvatsara contains twenty-four parvas. Fifth abhivardhana samvatsara contains twenty-six parvas. Thus the five-year-cycle contains 124 parvas (half-lunar-months) in all."

This is also explicitly stated in JP. 8.

Evidently, a five-year-cycle = 124 parvas (half-lunar-months)
= 62 lunar months

First, second and fourth (lunar) samvatsaras contain twenty-four parvas or twelve lunar months each and third and fifth (abhivardhana or lustfully increased) samvatsaras contain twenty-six parvas or thirteen lunar months each. The process of intercalation will be critically examined in due course (see 6.9).

3. PRAMĀṆA SAMVATSARA (Authentic Year)

Pramāṇa samvatsara (authentic year) implies a notion of standard measure of an year. As regards the diversity of pramāṇa samvatsaras (authentic years), SP. 10.20.4 states : (Quotation No. 6 1-4)

i.e. "There are five kinds of pramāṇa samvatsaras (authentic years) viz. nākṣatric (asterismic), lunar, ṛtu (seasonal), solar (and) abhivardhana ('lustfully increased' year denoting a lunar year increased by an intercalary lunar month)."

Regarding the mutual comparability of various pramāṇa samvatsaras (authentic years), SP. 12.12 states : (Quotation No. 6.1-5)

i.e. "Fifty-seven months 7 days $11\frac{23}{62}$ muhūrtas of abhivardhana months (= 57 $\frac{3}{13}$ abhivardhana months) i.e. increased months (twelve of which make an abhivardhana samvatsara i.e. lunar year increased by an intercalary lunar month), sixty solar months, sixty-one ṛtu (seasonal) months, sixty-two lunar months (and) sixty-seven nakṣatra months (lunar sidereal revolutions) be multiplied by 156 and then divided by twelve (leading to a product obtained by net multiplication with $\frac{156}{12}$

=13 only) ;then 744 abhivardhana months, 780 solar months, 793 ṛtu (seasonal) months, 806 lunar months (and) 871 nakṣatra months (lunar sidereal revolutions) are all equal."

Thus we have

$57\frac{3}{13}$ abhivardhana months = 60 solar months

= 61 ṛtu (seasonal) months

= 62 lunar months

= 67 nakṣatra months (lunar sidereal revolutions ... ... (6.1-3)

Multiplying both sides by 156 and then dividing by twelve (leading to a product obtained by a net multiplication with 13), we have

744 abhivardhana months = 780 solar months

= 793 ṛtu (seasonal) months

= 806 lunar months ... ...(6.1-4)

= 871 nakṣatra months (lunar sidereal revolutions)

Evidently, the eq. No. (6.1-4) depicts an integral relationship between different kinds of months. Thus a period of thirteen quinquennial cycles serves the purpose of a bigger cycle of sixty-five lunar samvatsaras (lunar years) which begins when all the different months begin and also close simultaneously. It is quite probable that such an approach might have been adopted as regards the kinematical studies of jupiter which led to the emergence of sixty-year-cycle of Jovian years i.e. jupiter's sidereal revolution and the five-year-cycle begin and close simultaneously once in a sixty-year-cycle.

Now a remark may be made regarding the number of abhivardhana months in a five-year-cycle. We know that a five-year-cycle has

62 lunar months = 1830 days

$\therefore$ 1 lunar month $= 29\frac{32}{62}$ days

Now $\because$ 1 abhivardhana samvatsara = 12 lunar months

or 12 abhivardhana months $= 383\frac{44}{62}$ days

$\therefore$ 1 abhivardhana month $= 31\frac{121}{124}$ days

$\therefore$ Number of abhivardhana months

in a five-year-cycle $= 1830 \div 31\frac{121}{124}$

$= 57\frac{3}{13}$

The length of an abhivardhana month and its number in a five-year-cycle are of theoretical interest only. However this has led to the development of theory of integral relationship between different kinds of months.

Now, multiplying with twelve on both sides of eq. No. (6.1-4), we get the integral relation between different samvatsaras (years' i.e.

744 abhivardhana samvatsaras = 780 solar samvatsaras
= 793 ṛtu (seasonal) samvatsaras ... (6 1-5)
= 806 lunar samvatsaras
= 871 nākṣatric samvatsaras

($\because$ 1 samvatsara = 12 months peculiar to that samvatsara)

This is a standard relation between different pramāṇa samvatsaras (authentic years). Now the rationale of multiplying the eq. No (6.1-3) by 156 and then dividing by 12 (and not multiplying by 13 only) is also obvious. Dividing by 12 on both sides of eq. No. (6.1.-3), the relation between different samvatsaras (years) is obtained as

$$\left(\frac{57\frac{3}{13}}{12} = \right)\frac{744}{13\times 12}$$

abhivardhana samvatsaras $= \frac{60}{12}$ solar years

$$= \frac{61}{12} \text{ ṛtu (seasonal) years} \quad ..(6.1\text{-}6)$$

$$= \frac{62}{12} \text{ lunar years}$$

$$= \frac{67}{12} \text{ nakṣatra years}$$

Evidently to get integral relation between different samvatsaras, eq. No (6.1-6) should be multiplied on both sides with 156. In other words, it is just equivalent to multiply with 156 and then divide with 12 on both sides of eq. No. (6.1-3).

Besides, it may be remarked that the integral relation between different samvatsaras (years) implies a bigger cycle of 780 years which is, incidently, 13 times the sixty-year-cycle.

4. **LAKSANA SAMVATSARA (Symptomatic Year)**

As regards the types of lakṣaṇa samvatsaras (symptomatic years), SP. 10.20.5 states :

> i.e "There are five kinds of lakṣaṇa samvatsaras (symptomatic years), viz. nākṣatric (asterismic), lunar, ṛtu, (seasonal), solar (and) abhivardhana (lustfully increased)."

The word 'lakṣaṇa (symptom)[46] indicates that a lakṣaṇa samvatsara (symptomatic year) is determined by the natural lakṣaṇas or seasonal indications. The several seasonal indications employed in the determination of lakṣaṇa samvatsaras (symptomatic years) are stated in SP. 10.20 as : (Quotation No. 6.1-7)

> i.e. "Timely the nakṣatra (asterism) occults (moon) ; season may be over ; (it is) neither too hot nor too cold ; (and) rains may be sufficient. (These lakṣaṇas or symptoms determine) the nākṣatric samvatsara (asterismic year) (1).

Timely the nakṣatra occults moon on pūrṇimā (full moon day) ; nakṣatra (asterism) may be odd ; rains may be sufficient ; (and) (the weather may be) severe ; that is the lunar samvatsara (year) (2).

When the plants grow in the odd time ; flowers grow with (proper) season ; (and) rains may be timely ; that is the ṛtu samvatsara (seasonal year) (3).

With the little rains, water, flowers (and) fruit ; grains may be produced in abundance ; that is the solar samvatsara (4).

When kṣana (moment or a small measure of time), lava (a small measure of time see 2.1), day, (and) season change with respect to the change in sunshine ; rains are too much ; that is the abhivardhana samvatsara (lustfully increased year) (5)."

The method of determination of lakṣaṇa samvatsaras (symptomatic years) is parallel to Egyptian's way of reckoning the year from the epoch river Nile was in spate. Lakṣaṇa samvatsaras (symptomatic years) are still of much importance for farmers for regulating their agricultural activities.

5. **SANICCHARA SAMVATSARA (Saturn Year)**

Sanicchara samvatsara (saturn year), as its name suggests, exhibits some Jainian trends towards kinematical studies of saturn. In this context, SP. 10 20 states : (Quotation No. 6.1-8)

i.e. "There are twenty-eight kinds of sanicchara samvatsaras (saturn years), viz. Abhijit (α Lyrae), Śravaṇa (α Aquilae) etc. upto Uttarāṣāḍhā (σ Sagittarii). The mahāgraha (big planet) (for the concept of mahāgraha, see 8.5) sanicchara (saturn) moves among all the nakṣatras (asterisms) in thirty samvatsaras (years)."

This is also explicitly stated in JP. 8.

Evidently, the length of a sanicchara samvatsara (saturn year) is equal to saturn's stay by mean motion in one nakṣatra (asterism) and the samvatsara (year) is called after the name of nakṣatra (asterism) occupied by saturn. Besides, corresponding to twenty eight nakṣatras (asterisms) we also have

1 sidereal revolution of saturn = 28 sanicchara samvatsaras (saturn years)
= 30 samvatsaras (years) (see quot. No. 6.1-8)
= 6 five-year-cycles
= 6 × 1830 days ($\because$ a five-year-cycle = 1830 days)
= 10980 days ... ...(6.1-7)

The modern length of sidereal period of saturn is 10759.23 days.[5]

$$\text{Error} = 10980 - 10759 = +221 \text{ days}$$

$$= \frac{221}{10759} \times 100 = +2\% \text{ approx.}$$

Besides, it may be noted that quot. No. (6 1 8) does not make it clear whether thirty samvatsaras (equivalent to twenty-eight sanicchara samvatsaras) are solar (six five-year-cycles as we have taken in the above case) or lunar. Suppose that the thirty samavtsaras are lunar; thus we have

1 sidereal revolution of saturn

$$= 30 \text{ (lunar) samvatsaras}$$

$$= 10625\frac{50}{62} \text{ days}$$

($\because$ 1 lunar samvatsara

i.e. 12 lunar months $= 354\frac{12}{62}$ days)

Deviation from the modern value $= 10626 - 10759 = -133$ days

$$= -\frac{133 \times 100}{10759} = -1.2\% \text{ approx.}$$

However, it may be concluded that the twenty-eight-year-cycle of sanicchara samvatsaras (saturn years) seems to have been intentionally devised to find out a better cycle of samvatsaras (years). Undoubtedly it exhibits Jainian treads towards kinematical studies of saturn.

In conclusion, it may be remarked that Jainas had some trends towards kinematical planetary studies like those of jupiter and saturn. Consequently they attempted to reform five-year-cycle and

develop their notions of bigger cycles like those of twelve-year-cycle of nakṣatra samvatsaras (asterism years) (which further led to the emergence of sixty-year-cycle of Jovian years) and twenty-eight-year-cycle of sanicchara samvatsaras (saturn years) etc. The tradition of finding an integral relation between different kinds of samvatsaras (years) (see eq. No. 6.1-5) suggests the probable course of gradual emergence of the concept of a mahāyuga (bigger cycle) containing integral number of sidereal revolutions of planets. For example, we find in Siddhāntic texts that all the planets start and close their sidereal revolutions simultaneously once in a period of 432000 years.[41]

6.2 *MONTH*

A month is traditionally known as the length of period equivalent to one twelfth year. The Vedic names of twelve months in an year are stated in Taittirīya Sanhitā. TRS.4.4.11 states as : (Quotation No. 6 2-1).

> *i.e.* "Madhu and Mādhava are the (two) months of Spring ; Śukra and Śuci of Summer ; Nabhas and Nabhasya of Rainy season; Iṣa and Ūrja of Autumn; Sahas and Sahasya of late Autumn; and Tapas and Tapasya of Śiśira (Winter)."

Jainas had a different nomenclature of months. In this context, JP 8 states : (Quotation No. 6.2-2).

> *i.e.* "There are twelve months in a samvatsara (year). Their nomenclature is twofold—Laukika (prevalent) (and) Lokottara (non-prevalent). Laukika (prevalent) names of months are Śrāvaṇa, Bhādrapada, etc. upto Aṣāḍha. Lokottara (non-prevalent) names of months are Abhinandita, Supratiṣṭhata, Vijaya, Prītivardhana, Sejāśreya, Śiva, Śiśireya, Himavanta, Vasanta, Kusumasambhava, Nidāgha, (and) Vanavirodha."

A conspicuous picture of month-names is shown in table No. (6.2-1).

TABLE NO. 6.2-1
(JAINA NAMES OF MONTHS)

Sr. No.	Laukika (prevalent)	Lokottara (non-prevalent)
1.	Śrāvaṇa (5)*	Abhinandita
2.	Bhādrapada (6)	Supratiṣṭhata
3.	Āśvina (7)	Vijaya
4.	Kārtika (8)	Prītivardhana
5.	Mārgaśīrṣa (9)	Sejāśreya
6.	Pauṣa (10)	Śiva
7.	Māgha (11)	Śiśireya
8.	Phālguna (12)	Himavanta
9.	Caitra (1)	Vasanta
10.	Vaiśākha (2)	Kusumasambhava
11.	Jyeṣṭha (3)	Nidāgha
12.	Aṣāḍha (4)	Vanavirodha

*Numbers in brackets indicate serial number of corresponding lunar months of current Hindu calendar.

Evidently, laukika (prevalent) names resemble with the popular Hindu names[42] of months. The Vedic names of months are althogether different from Jaina laukika (prevalant) and lokottara (non-prevalent) names. The lokottara (non-prevalent) names are peculiar to Jaina astronomical thought. However, Dixit writes about Vedāṅga Jyotiṣa period that no solar months had any independent names and these were perhaps named as Caitra (first lunar month of Hindu calender), Vaiśākha etc.[8] but his speculation is easily refutable. The terms Caitra etc. were not in vogue in the Sanhitā (a class of Vedic literature) and Brāhmaṇic (a class of Vedic literature) periods. Only the Jaina canonical texts have the first explicit reference to these names called laukika (prevalent) names of months. Besides, it may also be noted that Jaina list of months starts from Śrāvaṇa instead of Caitra, the first of months according to Siddhāntic texts. This is probably because the first point of reckoning of year was shifted from Winter solstice to Vernal equinox at the advent of Siddhāntic period.

It cannot be ascertained how far lokottara names may be taken as alternative to the Vedic names of months like Madhu etc.

Now as regards the length of months, it may be recalled that there are 5 kinds of pramāṇa samvatsaras (authentic years). Different months have different lengths corresponding to different lengths of different years respectively. A spectacular view may be had from table No. 6.2-2.

TABLE NO. 6.2-2
LENGHS OF PRAMĀṆA SAVATSARAS (AUTHENTIC YEARS) AND MONTHS

Sr. No.	*Name of samvatsara (year) or month.*	*Length of samvatsara (days)*	*Length of month (days)*	*Length of the 5-year cycle (months)*
1.	Nākṣatric (asterismic)	$327\frac{51}{67}$	$27\frac{21}{67}$	67
2.	Lunar	$354\frac{12}{62}$	$29\frac{32}{62}$	62
3.	Ṛtu (seasonal)	360	30	61
4.	Solar	360	$30\frac{31}{62}$	60
5.	Abhivardhana ('lustfully increased' with intercalation)	$382\frac{44}{62}$	$31\frac{121}{124}$	$57\frac{3}{13}$

It may be remarked that abhivardhana samvatsara (lustfully increased year) contains thirteen lunar months. Taittirīya Brāhmaṇa (T B. 3.10.1) also gives thirteen names of months apparently including that of intercalary month. Jainas have further perpetuated the length of an abhivardhana samvatsara by founding the concept of an abhivardhana month such that twelve of them make an abhivardhana samvatsara. The concept of abhivardhana month is of theoretical interest giving due credit to the method of intercalation.

6.3 *DAY*

(a) *NAMES OF DAYS*

A month has two parvas (half-months). In this context JP.8 states : (Quotation No. 6.3-1)

"How many parvas (half-months) does a month have ?
(A month has) two parvas (half-months), viz. dark half (and) bright half."

Each parva (half month) contains fifteen days and fifteen nights. In this context, JP. 8 states : (Quotation No. 6.3-2)

"How many days are there in a pakṣa (half-month) ?
There are fifteen days, viz. prtipada (first) day, second day, etc. upto fifteenth day.

What are the names of these fifteen days ?
There are fifteen names, viz. Pūrvāṅga, Sidhamanorama, Manohara, Yaśobhadra, Yaśodhara, Sarvakāma samṛddha, Indra mūrddhābhisikta, Saumanasa, Dhanañjaya, Arthasiddhi, Abhijat, Atyaśana, Śatañjaya, Agniveśa, Upaśama.

How many nights are there in a pakṣa (half-month) ?
There are fifteen nights viz. pratipada (first) night, second night, etc. upto fifteenth night.

What are the names of these fifteen nights ?
There are fifteen names, viz. Uttama, Sunakṣatra, elāvacca, Yaśodharā, Somanasā, Srīsanbhāta. Vijaya, Vejayantī, Jayantī, Aparājitā, Iccha, Samāhārā, Teja, Atitjā, Devānanda.

This shows that the names of days or nights were called after the ordinal numbers of days or nights in a pakṣa (half-month). Later days or nights in a pakṣa (half-month) were assigned a different name each. In Rigvedic times, names of days were called after the names of nakṣatras (asterisms). In this context, Rigveda Sanhitā X.85.13 states : (Quotation No. 6.3-3)

"The (dowry) of cows which was given by Savitā (sun) had already gone ahead of Surya. They drive the cows on Aghā (Maghā i.e. α Leonis) nakṣatra (day). The daughter was carried away on Arjunī (Phalguṇī *i.e.* δ Leonis) star day."

Thus it seems plausible that in Vedic times, there was a cycle of twenty-eight days corresponding to the number of twenty-eight nakṣatras (asterisms). The Jainas reduced it to a smaller cycle of fifteen days and they devised a nomenclature of fifteen days (and

corresponding fifteen nights also). This method of counting the days was also in vogue among the Jews who reckoned days by ordinal numbers—the first, second...seventh day. Their first day is Saturday. The seven-days week was however unknown to the classical Greeks, the Romans, the Hindus and early Christians. It was introduced into the Christian world by an edict of Roman emperior Constantine, about 323 A.D., who changed the Sabbath to the Lord's day (Sunday), the week day next to the Jewish Sabbath i.e. Saturday. In India, the week-days occur in inscriptions only from 484 A.D. but not in inscriptions of 300 A.D.[8] This suggests that Jaina system of reckoning the days in a half-month might have remained in vogue probably upto 300 A D. and week-days were introduced in the period 300-484 A.D.

However, it is worthy of note that there occurs a Vedic reference to a seven-day-week. In this context, AJ, Verse 63 states as : (Quotation No. 6.3-4)

"Sun, moon, mars, mercury, jupiter, venus, and saturn are lords of the seven days."

It seems therefore envisagable that either the Vedic text is a later addition to AJ or the relevant Jain text belongs to a remote antiquity. The latter view seems to be more plausible because Jaina astronomical system formed part and parcel of Jaina Philosophy and it might have been developed through many centuries before it was held in high esteem at the time of twenty-fourth tīrthaṅkara (ford-maker), Lord Mahavīra. It may, of course, be envisaged that some Jaina text parallel to AJ text as referred to above may still be missing. However, it may also be contemplated that the seven-day week might have had a connection with Jainian notion of seven tārakagrahas (star planets, viz. sun, moon, mars, mercury, jupiter, venus and saturn) leaving aside two shadowy tārakagrahas rāhu and ketu (see 8.5). However, it cannot be ascertained whether or not Jainas had actually conceived such a notion of seven-day-week.

(b) *Length of Day* :

The ancients reckoned the length of day in a great variety of ways. The Babylonians reckoned the day from sunrise to

sunrise ; the Athenians from sunset to sunset ; the Umbrians from noon to noon ; the Roman priest, Egyptians and Hiparchus from midnight to midnight and the common people every where from dawn to dark (a luce ad tenebras) which was the ancient and ordinary meaning of day among the Israelites also. Thus the word 'day' embodied a two-fold meaning i.e. the period of daylight on one hand and including day's inseparable accompaniment, the night, on the other.[38] Jainas reckoned the length of an ahorātra (day and night) from sunrise to sunrise. Like Babylonian hours (equal hours counted from sunrise to sunrise) and Italian or Bohemian hours (equal hours counted from sunset to sunset),[48] Jainas had divided an ahorātra (day and night) into equal muhūrtas (1 muhūrta = 48 minutes) counted from sunrise to sunrise.

The north-south motion of sun over various solar maṇḍalas (diurnal circles of sun) has a direct bearing upon the rate of change in length of day (daylight). In this context, SP.1.4.3 states as : (Quotion No. 6.3-5)

"When the two suns move on the innermost maṇḍala (diurnal orbit on Summer solstice day), the day (daylight) is of eighteen muhūrtas (1 muhūrta = 48 minutes) and the night of twelve muhūrtas. On the first ahorātra (day and night) of the new samvatsara (year), the (two) suns move on the second to the innermost maṇḍala. When the two suns move on the second to the innermost maṇḍala, the day is of '$18-\frac{2}{61}$' $\left(=17\frac{59}{61}\right)$ muhūrtas and the night of $12\frac{2}{61}$ muhūrtas. On the second ahorātra, the two suns move on third to the innermost maṇḍala when the two suns move on third to the innermost maṇḍala, the day is of '$18-\frac{4}{61}$' $\left(=17\frac{57}{61}\right)$ muhūrtas and night of $12\frac{4}{61}$ muhūrtas

Likewise, the (two) suns moving on maṇḍala to maṇḍala, reach the outermost maṇḍala (diurnal orbit on winter solstice

day) ; when the two suns move on the outermost maṇḍala, the day is of twelve muhūrtas and the night of eighteen muhūrtas. This happens in the first six months."

This is explicitly stated in BS. 315 also.[10]

It is evident that length of daylight goes on decreasing as the sun moves from the innermost maṇḍala towards the outermost maṇḍala i.e. from Summer solstice day towards Winter solstice day in the first six months.

Let the length (in muhūrtas) of any day (daylight) = m It is obviously seen by inspection from quot. No. (6.3-5) that for the first six months, the rate of change in length of daylight ;

$$\dot{m} = -\frac{2}{61} \text{ muhūrtas/day}$$

Integrating on both sides, we have

$$m = -\int_{O}^{n} \frac{2}{61}\, dt + m_0$$

or $$m = -\frac{2}{61} n + m_0 \quad \ldots \ldots \ldots \ldots \ldots \ldots \ldots (6.3\text{-}1)$$

Where n = number of days from Summer solstice day, or yet to go for Summer solstice day.

and m_0 = length of daylight on Summer solstice day.

Applying initial conditions on Summer solstice day,

i.e. n = O, m = 18 muhūrtas,

from eq. No. (6.3-1), we have

$$m = -\frac{2}{61} n + 18 \quad \ldots \ldots \ldots \ldots \ldots \ldots \ldots (6.3\text{-}2)$$

The length of any (daylight) can easily be computed from eq. No. (6.3-2).

A similar formula for obtaining the length of daylight is also found in Vj, Rk. recension,[18] verse 22, which is stated as : (Quotation No. 6.3-6)

"Find the number of days elapsed after uttarāyana (northward motion of sun) or number of days yet to go for dakṣiṇāyana (southward motion of sun) ; multiply the number by two and divide the product by 61. Add 12 to the quotient getting the measure of a day (daylight) in muhūrtas."

This gives us, similar to eq. No. (6.3-2), an equation given below :

$$m = \frac{2}{61} n_1 + 12 \quad \dots \dots \dots \dots \dots \dots \dots \quad \dots (6.3\text{-}3)$$

where n_1 = number of days from Winter solstice day or yet to go for Winter solstice day.

Arthaśāstra[11] gives the length of day light as fifteen muhūrtas at the equinoxes, with an increase or decrease of one muhūrta a month as one proceeds from an equinox towards respectively Summer or Winter solstices ; thereby the longest day (daylight) becomes eighteen muhūrtas and the shortest twelve muhūrtas. An identical method[12] for computing the daylight is also found in SKV. Thus the ratio of maximum and minimum lengths of daylight becomes 3 : 2.

Pingree[13] remarks that one needs only multiply the Babylonian beru (double hours) by 2½ to produce the Indian table of muhūrtas. His views are based on the claim that the ratio 3 : 2 of longest and shortest lengths of daylight indicates a terrestrial latitude of about 35°N, that is, somewhat north of latitude of Babylon. But as Kaye[14] points out that the ratio 3 : 2 suits also to Gandhāra in India because the actual ratio is 1.45 for Babylon and 1.42 for Gandhāra. The difference is not very large. By applying refraction (4½ minutes morning and evening each), total daylight for Babylon is fourteen hours and twenty-one minutes and night nine hours and thirty-nine minutes. The ratio becomes now 1.49. Similarly for Gandhāra it becomes 1.46 which is not much different from 1.5 as for Babylon. This suggests that the ratio 3 : 2 might have not necessarily been obtained from Babylonian sources. In this context, the following points are also worth noticing :

(1) The ratio 3 : 2 of maximum and minimum lengths of daylight is available in VJ, Jaina canonical literature and several other contemporary works in ancient India whereas it is found in only one of the Babylonian tablets.

(2) The ratio 3 : 2 has been used for centuries together in ancient Indian literature over a big period extending from remote Vedic times upto the fag end of period of pre-Siddhāntic Jaina School of astronomy. It is not worth-believing that during this period only the ratio 3 : 2 was obtained from Babylonian sources and not week-days, ecliptic signs and epicyclic theory etc. as they are not less important than this ratio.

(3) Jainas had studied minutely the varying character of length of daylight. In this context, SP. 6.2 states as : (Quotation No. 6.3-7)

> "Sun's light remains constant for thirty muhūrtas. Sun's light does not remain constant after that. Sun's light decreases for six months and (then) sun's light increases for six months."

This indicates that the sun remains stationary for thirty muhūrtas or a day and night before it starts its southward course. Thus the observation relates to the determination of Summer solstice Summer solstice compared with three days' virāj[16] (stationary position of sun) of AB was therefore determined upto one day only Observational skill of this order suggests that Jainas might have discovered the fact that maximum length of daylight varies from place to place. Maximum length of daylight at Gandhāra is greater than that at any other place in ancient India. Thus Gandhāra having the maxima of maximum lengths of daylight for all places in ancient India, probably served the purposes like those of a standard station for the purposes of civil reckoning of the length of any day (daylight). These variations of time-lengths of daylight used over different places other than Gandhāra apparently did not affect the simple Indian mode of life just as the simple Babylonian

mode of life was also not affected, as Henry C. King[28] remarks, by the variations of temporal hours over the seasons.

(4) The ratio 3 : 2 has a close relation with 183 days (half the annual course of sun) i.e. $\frac{2}{61}$ muhūrtas being the daily variation in the length of daylight, meaning that the year consisted of 366 days. Babylonians never had an year of 366 days. This argument may also be called as vilomatarka (converse logic). But it is to be noted that the theory of five-year-cycle comprising of five years of 366 days each, had been held in high esteem since Jyotiṣa Vedāṅgam period. We do not find any reference to an earlier use of a different length of year which could be supposed to have been increased to 366 days.

Besides, simplicity of the relation between the ratio 3 : 2 and 183 days (half the annual course of sun) appears to suggest that Jainas might have searched for a standard place like Gandhāra where a simple relation of this order holds good. It is worth-mentioning here that in China,[15] in the reign of the Emperor Wu (who had issued an imperial edict in B.C. 104 to reform the calendar) in the former Han, the difference (twenty quarters) between maximum and minimum lengths of daylight was divided in a zigzag manner for simplicity sake into 180 days whereas the actual length of an year was taken a little more than 365 days. An alike reason that ancient Indians also, for simplicity sake, might have increased the length of an year to 366 days, carries not much weight in the light of the fact that Gandhāra had been a renowned seat of ancient Indian culture and it was not an abode of any mythological creatures. As Gandhāra and Babylon are situated on latitudes very close to each other, the ratio 3 : 2 might have been found independently over these two places.

(5) Like Vedic tradition, Jainas continued to use equal distribution of six muhūrtas over 183 days of an ayana (half the

annual course of sun) following the notion of average change of declination of sun during this period (see 5.1). A similar methodology of computing the length of daylight also prevailed among the ancient Chinese[15] who equally divided twenty quarters, the difference between length of day or night at Winter solstice and that at Summer solstice, in 180 days (the interval between Winter and Summer solstices). It was in the fourteenth year of Yungyuan are (A D. 102) when Ho Jung and Shu Ch' eng-fang reformed the clepsydra system by an imperial edict in which they discarded the equal division of one quarter in nine days but instead took the day either to increase or to decrease by one quarter for every 2.4 Chinese degrees (one-tenth of the obliquity of ecliptic) change in sun's declination. Since the time of twilight at a given observatory depends tout a fait upon Sun's declination, it is theoretically right either to increase or to decrease the length of daylight in accordance with the change in declination but because the times of twilignt do not change proportionately to the change of sun's declination, so this method again involves an approximation. This shows that the methods of computing the day-lengths on the average basis were customary among the ancient peoples. Jainas were no exception to such traditions Therefore the Indian use of a linear zigzag function which was employed by the Babylonians is no solid proof for ascertaining the transportation of the use of a linear zigzag function from Babylon to India. Likewise Vedic and Jainian use of a linear zigzag function for calculating the length of daylight is no authentic sign of the Babylonians origin of the ratio 3 : 2. Therefore, Pingree's views[13] in this connection are questionable.

(6) Now let us see if the error due to rate of flow of water in time-measurements by means of a water-clock is also taken into account for the determination of ratio of maximum and minimum lengths of daylight.

There were two kinds of water-clocks-inflowing and outflowing. According to Viṣṇu Purāṇa[43] (Vip. 3.6.7-8), a copper vessel of 12½ palas weight has at its bottom a hole made by a

golden rod four aṅgulas (finger-widths) long and of four māśās weight. The vessel is made to float on the surface of water and it sinks after a ghaṭī (= 24 minutes). The escape hole of the water clock is also described in an alike manner in SKV[13] and Arthaśāstra.[11] According to VJ (Rk. recension, verse 7),[16] the increase in daylight and the decrease in night time in sun's northern course is a prastha of water and in sun's southern course it is the reverse. Thus the amount of water to be poured into the waterclock is increased by One prastha a day during sun's northern course, that is, from Winter solstice to Summer solstice and vice versa. So the amount of water to be poured into the water clock is minimum at Winter solstice and maximum at Summer solstice. Besides, VJ (Yajur recension, verse 24)[18] also gives nāḍikā (= 24 minutes) in terms of liquid measure and it runs as :[44]

> "The vessel known as 'āḍhaka' holds fifty palas of water. Measure one droṇa of water with it. Throw away from it water equal to three kuḍavas in volume. Then the time needed for the remaining water (to trickle away) is known as one nāḍikā."

An outflowing water clock is also mentioned by Sphujidhvaja[18] (c A.D. 269/270) and by Varāhamihira.[18]

Besides, a reference to the use of an outflowing water-clock is also found in Babylonian cunieform text, mul Apin.[45]

In the light of this discussion, it may be contemplated that the use of an outflowing water clock was more prevalent in ancient times. Ancient Indians had standardized ghaṭī or nāḍikā (= 24 minutes) as the fundamental unit of time. Obviously, the maximum and the minimum lengths of daylight were measured in units of ghaṭīs or nāḍikās. This was done by counting the number of times the amount of water equivalent to a ghaṭi or nāḍikā was to be poured into the water clock on a particular day. Now it will be shown that the ratio of amounts of water to be poured into the water clock on the greatest and the shortest days (daylights) respectively is different than the ratio of maximum and

minimum actual lengths of daylight. Consider a cylindrical vessel as a water-clock.

Let a = area of cross-section of orifice

h = height of liquid above orifice

v = velocity of liquid at orifice

A = area of cross-section of cylindrical vessel (water-clock)

V = volume of liquid in water-clock

g = acceleration due to gravity

$\therefore \quad V = Ah$

Differentiating both sides with respect to t, we have

$$\frac{dV}{dt} = A\frac{dh}{dt} \qquad \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots (6.3\text{-}4)$$

Now according to Bernoulli's theorem,[46] we have that

$$v = \sqrt{2gh}$$

(This result is also known as Torricelli's theorem)[46]

Rate of flow of water, $\frac{dv}{dt} = av$

$$\text{or } \frac{dV}{dt} = a.\ \sqrt{2gh} \qquad \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots (6.3.\text{-}5)$$

$\therefore$ From eq. No. (6.3-4) and eq. No. (6.3-5), we haue

$$A\frac{dh}{dt} = a.\ \sqrt{2gh}$$

$$\text{or } t' = -\int_{-h'}^{0} \frac{A}{a\sqrt{2g}} \cdot \frac{dh}{\sqrt{h}}$$

($\because$ h increases in the negative direction from maximum h' to zero, as $t \longrightarrow t'$)

Where t' = total time required for the whole of liquid to trickle down,

and h' = initial height of liquid above orifice

$$\therefore \quad t' = \frac{A}{a\sqrt{2g}} \cdot 2\sqrt{h} \qquad \ldots\ldots\ldots\ldots\ldots (6.3\text{-}6)$$

Now when $t' = 1$ ghaṭikā or naḍikā (= 24 minutes)

let $h' = h_0$

and $V = V_0$ (water equivalent to ghaṭikā or nāḍikā)

$\therefore$ from eq No. (6.3-6) we have

$$1 = \frac{A}{a\sqrt{2g}} \cdot 2\sqrt{h_0} \qquad \ldots\ldots\ldots\ldots\ldots (6.3\text{-}7)$$

Now on the shortest daylight (= 24 ghaṭikās or nāḍikās),

$t' = t_{min}$ (say)

$h' = h_{min}$ (say)

$V = V_{min} = 24\ V_0$ ($\because V_{min}$ = Water equivalent to 24 ghaṭikās or nāḍikās)

Or $Ah_{min} = 24\ Ah_0$

or $h_{min} = 24\ h_0$

$\therefore$ from eq. No. (6.3-6), we have

$$t_{min} = \frac{A}{a\sqrt{2g}} \cdot 2\sqrt{24\ h_0} \qquad \ldots\ldots\ldots\ldots\ldots (6.3\text{-}8)$$

Similarly, on the greatest daylight (36 ghaṭikās or naḍikās)

$t' = t_{max}$ (say)

$h' = h_{max}$ (say)

$V = V_{max} = 36\ V_0$ ($\because V_{max}$ = Water equivalent to 36 ghaṭikās or nāḍikās)

or $Ah_{max} = 36\ Ah_0$

or $h_{max} = 36\ h_0$

∴ From eq. No. (6.3-6), we have

$$t_{max} = \frac{A}{a\sqrt{2g}} \cdot 2\sqrt{24\,h_0} \quad \ldots\ldots\ldots\ldots\ldots (6\ 3\text{-}9)$$

From eq. No. (6.3-8) and eq. No. (6.3-9), we have

$$\frac{t_{max}}{t_{min}} = \sqrt{\frac{36}{24}} = \sqrt{\frac{3}{2}} = \sqrt{1.5}$$

$$= 1.22 \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (6.3\text{-}10)$$

whereas

$$\frac{V_{max}}{V_{min}} = \frac{36}{24} = \frac{3}{2} = 1.5 \quad \ldots\ldots\ldots\ldots\ldots (6.3\text{-}11)$$

From eq. No. (6.3-10) and eq. No. (6.3-11), it is evident that

$$\frac{t_{max}}{t_{min}} = \sqrt{\frac{V_{max}}{V_{min}}} \neq \frac{V_{max}}{V_{min}}$$

This indicates that the ratio 3:2 represents actually the ratio of amounts of water to be poured into the water-clock on the greatest and the shortest days respectively. The actual ratio of maximum and minimum lengths of daylight is given as

$$\frac{t_{max}}{t_{min}} = 1.22$$

This ratio holds for a latitude 19°.6 North very near of that of Ujjainī, a renowned seat of ancient Indian culture.

Now this treatment may similarly be extended upon the determination of daily increment in the length of daylight. In sun's northern course, according to VJ (Rk. recension, Verse 7),[18] length of daylight increases by one prastha a day, with its minimum on Winter solstice day. Dixit has shown that one prastha of water is equal to 4/61 V_0 whereas V_0 denotes the amount of water poured into the water-clock such that the whole

of water V_0 trickles down in one ghaṭikā or nāḍikā. Thus the amount of water to be poured into the water clock is increased by 4/61 V_0 a day with its minimum amount at Winter solstice day and maximum amount at Summer solstice day.

Let

n = number of days since Winter solstice or yet to go for Winter solstice

V_n = amount of water to be poured into the water-clock on the nth day since Winter solstice etc.

h_n = height of water column on the nth day since Winter solstice etc.

$$\therefore \quad V_n = V_0 + \frac{4n}{61} V_0$$

$$\text{or} \quad V_n = \left(1 + \frac{4n}{61}\right) V_0 \quad \ldots \ldots \ldots \ldots \ldots \ldots \ldots (6.3\text{-}12)$$

Also we have

$$V_n = Ah_n \quad \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots (6.3\text{-}13)$$

$\therefore$ From eq. No. (6.3-12) and eq. No. (6.3-13), we have

$$h_n = \frac{1 + \frac{4n}{61}}{A} \cdot V_0$$

$$\text{or} \quad h_n = \left(1 + \frac{4n}{61}\right) h_0 \quad \ldots \ldots \ldots \ldots \ldots \ldots \ldots (6.3\text{-}14)$$

$$(\because \; V_0 = Ah_0)$$

Putting $t' = t_n$, $h' = h_n$, in eq. No. (6.3.6), we get

$$t_n = \frac{A}{a\sqrt{2g}} \cdot 2\sqrt{\left(1 + \frac{4n}{61}\right) h_0} \quad \ldots \ldots \ldots (6.3\text{-}15)$$

Similarly, we have

$$t_{n+1} = \frac{A}{a\sqrt{2g}} \cdot 2\sqrt{\left(1 + \frac{4(n+1)}{61}\right) h_0} \quad \ldots \ldots (6.3\text{-}16)$$

Subtracting eq. No. (6.3-15) from eq. No. (6.3-16), we have

$$t_{n+1}-t_n = \frac{A}{a\sqrt{2g}} \cdot \frac{2\sqrt{h_0}}{\sqrt{61}} \left(\sqrt{61+4(n+1)} - \sqrt{(61+4n)} \right) \quad \ldots \ldots \ldots \ldots (6.3\text{-}17)$$

or putting $\frac{A}{a\sqrt{2g}} \cdot \frac{2\sqrt{h_0}}{\sqrt{61}} = B$ (Constant), we have

$$t_{n+1}-t_n = B\left(\sqrt{61+4(n+1)} - \sqrt{(61+4n)} \right) \quad \ldots \ldots (6.3\text{-}18)$$

$\therefore$ On putting n = 1, 2, 3, ...183, we get

$$t_2 - t_1 = B\left(\sqrt{69} - \sqrt{65}\right) = .2443\ B$$

$$t_3 - t_2 = B\left(\sqrt{73} - \sqrt{69}\right) = .2374\ B$$

$$t_4 - t_3 = B\left(\sqrt{77} - \sqrt{73}\right) = .2310\ B$$

... ...

... ...

... ...

$$t_{182} - t_{181} = B\left(\sqrt{789} - \sqrt{785}\right) = .0706\ B$$

$$t_{183} - t_{182} = B\left(\sqrt{793} - \sqrt{789}\right) = .0714\ B$$

Obviously, $t_{n+1} - t_n$ decreases from Winter solstice upto Summer solstice and vice versa. So $t_{n+1} - t_n$ does not give its true value (minimum at solstices and maximum at equinoxes). But it is to be emphasized that $t_{n+1} - t_n$ does not give a constant value. This stands true for all physical situations. So the actual rate of increase in time-length of day (daylight) counted from Winter solstice to Summer solstice and vice versa cannot be generated through a simple linear zigzag function. It is however yet to be investigated if they had actually conceived this fact that rate of increase (or decrease) in length of daylight by one prastha a day involves the concept of a variable increment in length of daylight measured in actual time-units. It may be contemplated that this notion might have been prevalent in VJ time and therefore the need to devise a gnomonic experiment like that of AJ text might have been felt for standardization of muhūrta (= 48 minutes or

2 ghaṭīs or nāḍikās) in units of shadow-lengths on Equinoctial day.[47]

(7) It is also worthy of note that Vāsiṣṭha Siddhānta[48] (system of Vasiṣṭha) (see Varāhamihira's Pañca Siddhānthikā.[8]) gives 1591 and 2131 palas (2.5 palas = 1 minute) as the greatest and shortest lengths of daylight respectively. This suits for the latitude 22°.6 North which is very close to the latitude of Avantī (Ujjainī), a renowned seat of ancient Indian culture.

Conclusion :

In the light of the foregoing discussion, it may be concluded that the ratio 3 : 2 represents the ratio of amounts of water to be poured into the water clock on the greatest and the shortest days (daylights) respectively. The actual ratio of maximum lengths of daylight, on applying correction for the variable rate of flow of water through the orifice of water-clock, comes out to be $\sqrt{3} : \sqrt{2}$ and it holds for a latitude 19°.6 North very near to that of Ujjainī, a renowned seat of ancient Indian culture.

However Jainas had devised a gnomonic experiment for the measurement of time through shadow-lengths[49] and thus it might have been facilitated to find ratio of maximum and minimum lengths of daylight for any latitude of observer. The ratio of maximum and minimum lengths of daylight for Gandhāra is greater than that for any other place in ancient India. Thus in the post-Vedic Jaina period Gandhāra might have been chosen for the purposes like those of a standard station for the purposes of civil reckoning of the length of daylight. Gandhāra had also been a renowned seat of ancient Indian culture. Incidently the ratio 3 : 2 of maximum and minimum lengths of daylight for Gandhāra is equal to the ratio of amounts of water to be poured into the water clock on these respective days for a latitude 19°.6 North as discussed earlier However Jainas had admittedly obtained variation in length of daylight through a linear zigzag function. It is however contemplable that Gandhāra had served the purposes like those of a standard station in ancient India till the decline of Jaina School of Astronomy and the centre of astronomical activities in those times was again established at

about a latitude 22°.6 North very near to that of Avantī (Ujjainī) at about the period of compilation of VS.

It may also be worth mentioning here that Achaemenid Persians in the sixth century B.C had made conquests in north-west of India upto the valley of Sindh including Gandhāra At about the same time (549-525 B.C.) Syria, Phoenicia, Egypt and Greek establishments in Asia Minor also fell under the control of Persia. According to O P. Jaggi,[37] there was a certain exchange of knowledge between the civilizations of Egypt, Greece and India under the same Persian control. He further stresses upon evidences to show that Greek scholars visited India and vice versa. In the light of our investigations, it is, however, still an unsettled question to decide which borrowed the ratio 3 : 2 of maximum and minimum lengths of daylight from whom.

6.4 *TITHI (LUNAR DAY)* :

'Tithi' means 'lunar day'. The word 'Tithi' occurs in the Bahvrica Brāhmaṇa[31] at some places but the definition of tithi is stated in Aittiraiya Brāhmaṇa (AB. 32.10) which runs as follows : (Quotation No 6.4-1).

"Tithi is that period of time during which moon sets and rises again."

Thus tithi is defined as the length of a lunar sāvaṇa day (the interval between two consecutive moonrises), which is always longer than a civil day by about a muhūrta (48 minutes). The sun rises twenty-nine or thirty times and moon rises twenty-eight or twenty-nine times during a lunar month. So a lunar month will never contain thirty tithis of this order. This definition has not yet been found in any other Vedic or post-Vedāṅga text.

Tithi is also mentioned in VJ. However an exhaustive account of tithi is given in Jaina canonical literature. In this context, SP. 10.15 states : (Quotation No. 6.4-2).

"One pakṣa (half-month) has fifteen day tithis, viz. Nandā, Bhadrā, Jayā, Tūryā, Pūrṇā the fifth tithi ; the cycle repeats, Nandā, Bhadrā, Jayā, Tūryā, Pūrṇā ; the cycle repeats (once again), Nandā, Bhadrā, Jayā, Tūryā, Pūrṇā the fifteenth (tithi).

One pakṣa (half-month) has fifteen night tithis, viz. Ugāvatī, Bhogāvatī, Yaśavatī, Sarvārthasiddhā, Śubha ; the cycle repeats, Ugāvatī, Bhogāvatī, Yaśavatī, Sarvārthasiddhā, Śubha ; the cycle repeats (once again), Ugāvatī, Bhogāvatī, Yaśavatī, Sarvārthasiddhā, Śubha."

This is also explicitly stated in JP. 8.

It appears plausible that because in bright half of the lunar month, moon is seen in the day before or just before sunset and hence fifteen tithis might have been called as day tithis, and the other fifteen tithis as night tithis because moon is seen in the night time. Thus a lunar month consists of thirty tithis.

Now

$\because$ A five-year-cycle $= 62 \times 30 = 1860$ tithis

($\because$ a five-year-cycle $= 62$ lunar months)

The same number of tithis in a five-year-cycle is also found in VJ.[18]

Next we know that a five-year-cycle has

1860 tithis $=$ 1830 days

$$\therefore \quad 1 \text{ tithi} = \frac{61}{62} \text{ day}$$

$$= \left(1 - \frac{1}{62}\right) \text{day}$$

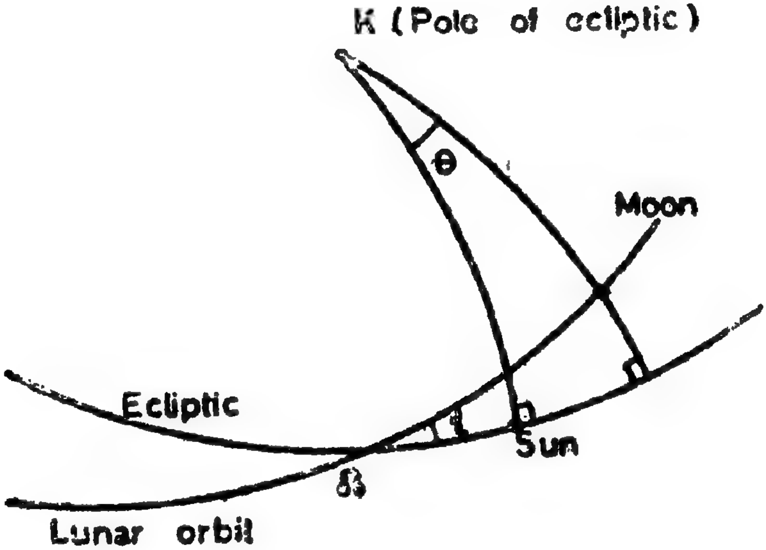
Thus by average motion, the number of tithis gains over the corresponding number of days by 1/62 per tithi or 1/61 per day. So the mean tithi and the day begin simultaneously once in every sixty-two tithis or sixty-one day. This also implies that the beginning point of tithis moves with respect to the beginning point of days by 1/62th day (day and night) a tithi. Therefore thirty-one tithis begin in daylight of the Equinoctial day and

thirty-one tithis in night. However, it may be recalled that moon completes one revolution with respect to sun in thirty tithis i.e.

30 tithis = 360°

∴ 1 tithi = 12°

i.e. moon moves 12° with respect to sun per tithi (see fig. No. 6.4-1). This is also the modern concept of tithi. Besides



λ_s = Longitude of sun

λ_m = Longitude of moon

$\theta = \lambda_m - \lambda_s$

T = Current Tithi (Current lunar day)

$= \theta/12$ ($\because$ 360° : θ° : : 30 : T)

Fig. No. 6.4.-1 : ***Calculation of current tithi (lunar day) based on lunar motion with respect to sun.***

according to the old School :[19] every tithi has a different length lying inbetween 54 and 65 ghaṭikās (1 ghaṭikā = 24 minutes) but the extreme durations of all tithis, according to dṛk-pakṣīya (observational) School, have different values each, 50.06 and 67.07 ghaṭikās (1 ghaṭikā = 24 minutes) being the minimum and the maximum of all.[20] Thus practically the beginning point of tithis does not move at the rate of 1/62th day a tithi and all the thirty tithis of a month cannot begin in either daylight or night ; but the beginning points of tithis in a lunar month are rather scattered over a day (day and night).[21] Empirically, it may be taken that about half the number of tithis in a lunar month begin in daylight and the other half in night time. Thus fifteen tithis beginning in daylight may be called as day tithis and the other fifteen tithis night tithis.

Alternately, any tithi partly falling in daylight and partly in night time might have been called by different names in daylight and night time respectively. The sum of the parts occurring in daylight of thirty tithis in a lunar month may be empirically equalled with fifteen tithis and the sum of the parts occurring in night time also with fifteen tithis ; hence the concept of fifteen day tithis and fifteen night tithis might have been developed.

In the light of foregoing discussion, although the mystery of nomenclature of day tithis and night tithis is yet to be unfolded, yet it is contemplable that this concept of day tithis and night tithis implies Jainian trends towards the study, albeit inadequately, of different lengths of tithis and of their beginning points scattered over a day (day and night).

Besides, it may be seen that the cycle of fifteen day (or night) tithis is composed of three times the corresponding cycle of five tithis. This is shown in table (6.4-1).

TABLE 6.4-1

NOMENCLATURE OF DAY TITHIS AND NIGHT TITHIS IN A LUNAR MONTH

Sr. No.	Day tithi	Number of tithi in			Night tithi
		I Cycle	II cycle	III cycle	
1.	Nandā	1	6	11	Ugāvatī
2.	Bhadrā	2	7	12	Bhogāvatī
3.	Jayā	3	8	13	Yaśavatī
4.	Tūrya	4	9	14	Sarvārthasiddhā
5.	Pūrṇā	5	10	15	Śubha

It may be remarked that even these days nomenclature of tithis alike to that of day tithis (see table 6.4-1) influences several liturgical performances of Hindus.

6.5 KARANA (HALF-TITHI OR HALF LUNAR DAY)

A karaṇa denotes the length of half-tithi (half lunar day). In Vedic period, a list of karaṇas is found in AJ wherein a classification of karaṇas responsible for auspicious and inauspicious acts has also been made. A complete list of karaṇas is also stated in Jaina canonical texts. JP. 8 states : (Quotation No. 6.5-1)

"There are eleven karaṇas (half-lunar days), viz. Bava, Bālava, Kaulava, Strīvilocana, Garādi, Vaṇijya Viṣṭi, Śakuni, Catuṣpada, Nāga (and) Kistudhana. Seven karaṇas are movable ; four karṇas are immovable. The seven movable karṇas are Bava, Bālava, Kaulava, Strītvilocana, Garādi, Vaṇijya, (and) Viṣṭi. The four immovable karṇas are Śakuni, Catuṣpada, Nāga, (and) Kintughana."

A list of karaṇas is also found in Gaṇivijjā Paiṇṇā[88] (verses 41-43).

All the karaṇas have been allocated to various tithis (lunar days). In this context, JP8 states : (Quotation No. 6.5-2).

"In the lunar bright half, on first night Bava karaṇa ; second day Bālava karaṇa, night Kaulava karaṇa ; third day Strīvilocana karaṇa, night Garādi karaṇa ; fourth day Vaṇijya, night Viṣṭi ; fifth day Bava karaṇa, night Bālava karaṇa ; sixth day Kaulava karaṇa, night Strīvilocana karaṇa ; seventh day Garādi karaṇa, night Vaṇijya karaṇa ; eighth day Viṣṭi karaṇa, night Bava karaṇa ; ninth day Bālava karaṇa, night Kaulava karaṇa, tenth day Strīvilocana karaṇa, night Garādi karaṇa ; eleventh day Vaṇijya karaṇa, night Viṣṭi karaṇa ; twelfth day Bava karaṇa, night Bālava karaṇa ; thirteenth day Kaulava karaṇa, night Strīvilocana karaṇa ; fourteenth day Garādi karaṇa, night Vaṇijya karaṇa ; Pūrṇimā day Viṣṭi karaṇa, night Bava karaṇa.

In the lunar dark half, on first day Bālava karaṇa, night Kaulava karaṇa ; second day Strīvilocana karaṇa, night Garādi karaṇa ; third day Vaṇijya karaṇa, night Viṣṭi karaṇa ; fourth Bava karaṇa, night Bālava karaṇa ; fifth day Kaulava karaṇa, night Strīvilocana karaṇa ; sixth day Garādi karaṇa, night Vaṇijya karaṇa ; seventh Viṣṭi karaṇa, night Bava karaṇa ; eighth day Bālava karaṇa, night Kaulava karaṇa ; ninth day Strīvilocana, night Garādi karaṇa ; tenth day Vaṇijya karaṇa, night Viṣṭi karaṇa ; eleventh day Bava karaṇa, night Bālava karaṇa ; twelfth day Kaulava karaṇa, night Strīvilocana ; thirteenth day Garādi karaṇa, night Vaṇijya karaṇa ; fourteenth day Viṣṭi karaṇa, night Śakuni karaṇa ; Amāvasyā day Catuṣpada karaṇa, night Nāga karaṇa.

On first day of lunar bright half, it is Kintughana karaṇa."

The above data are shown in table (6.5-1).

TABLE 6.5-1
TABLE OF KARAṆAS

Tithi	Lunar bright half		Lunar dark half	
	Day karaṇa	Night karaṇa	Day karaṇa	Night karaṇa
1	Kin*	1	2	3
2	2	3	4	5
3	4	5	6	7
4	6	7	1	2
5	1	2	3	4
6	3	4	5	6
7	5	6	7	1
8	7	1	2	3
9	2	3	4	5
10	4	5	6	7
11	6	7	1	2
12	1	2	3	4
13	3	4	5	6
14	5	6	7	Śak.
15	7	1	Cat.	Nāg.

*Names of Karaṇas : (1) Bave, (2) Bālava, (3) Kaulava, (4) Strīvilocana (Taitila), (5) Garādi, (6) Vaṇijya, (7) Viṣṭi. Then Śak = Śakunī, Cat = Catuṣpada, Nāg = Nāga, Kin = Kintughana

It is evident by inspection from table (6.5-1) that the immovable karaṇa are associated with particular half-tithis and they occur only once a month each, e.g. Śakuni occurs on fourteenth night of the lunar dark half. The movable karaṇas occur in rotation from the first night of lunar bright half upto fourteenth day of lunar dark half and each of them may occur at different days and

different nights. Every tithi has been divided into two karaṇas i.e. day karaṇa (first half of tithi) and night karaṇa (second half of tithi).

It seems plausible that first half of a tithi might have been called day karaṇa and the second half night karaṇa if the tithi commences in day time.[23] But all the tithis do not begin in day time (see 6.4), so the day karaṇa has no link with day light, but refers to the first half of lunar day (and not the solar or civil day). Similarly the night karaṇa refers to the second half of lunar day.

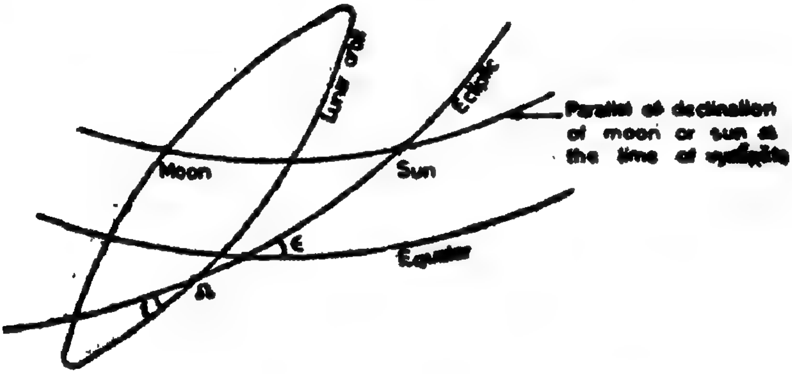


Fig. No. 6.6—1 (a)

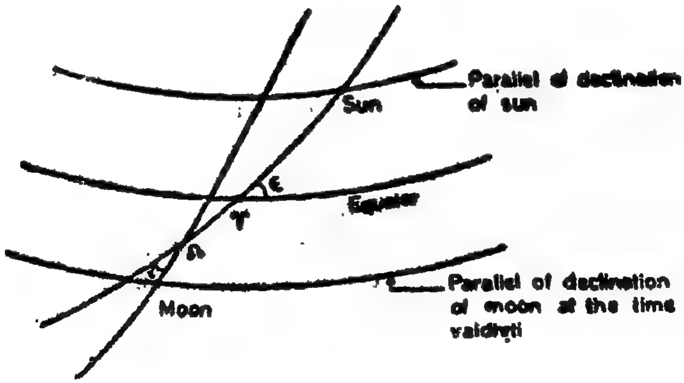


Fig. No. 6.6—1 (b)

Fig. No. 6.6-1 (a) : *Vyatīpata yogā (equal declinations of sun and moon occupying different ayanas).*

Fig. No. 6.6-1 (b) : *Vaidhṛti yoga (equal and opposite declinations of sun and moon occupying the same ayana).*

In AJ, names of dieties of karaṇas are also given. They include Dhanādhipa of Kaustubha karaṇa and Maṇibhadra of Vaṇijya karana. The names of the remaining dieties are those from the Vedas.[22] Names of dieties of karaṇas are not found in Jaina canonical literature. This part of JP might have been compiled probably earlier than AJ was composed. Besides, in AJ, Kinstughna, one of the stationary or immovable karaṇas, is substituted by Kaustubha. Tilak opines that this may be a writer's error.[23] It is, however, left for the linguists to see how far this change affects the chronology of AJ.

6.6. YOGA (COMBINATION)

"Yoga' means 'combination' and it denotes 'sum of longitudes of sun and moon' varying from zero to 360°. There is an equal amplitude system of twenty-seven yogas viz.

1. Viṣkumbha	10. Gaṇḍa	19. Prigha
2. Parīti	11. Vṛddhi	20. Śiva
3. Āyuṣmān	12. Dhruva	21. Siddha
4. Saubhāgya	13. Vyāghāta	22. Sādhya
5. Śobhana	14. Harṣaṇa	23. Śubha
6. Atigaṇḍa	15. Vajra	24. Śukla
7. Sukarmā	16. Siddhi	25. Brahma
8. Dhṛti	17. Vyatipāta	26. Indra
9. Śūla	18. Varīyān	27. Vaidhṛti

The various yogas (combinations) were later derived from two mahāpātas viz. vyatipāta and vaidhṛti. Vyatipāta occurs when sun and moon have the same declination but they occupy different ayanas (northern or southern journeys) i.e. sun moves southward and moon moves northward or vice versa (see fig. No. 6.6-1.a). Vaidhṛti occurs when sun and moon, both occupying the same ayana (northward or southward journey) have equal and opposite declinations (see fig. No. 6.6-1.b).

According to T.S. Kuppannashastrī[23] vyatipāta first occurs in Paitāmaha Siddhānta as seen from its condensation in Pañcasiddhāntikā (12.4). But according to H.P. Bhatt,[24] a reference to vyatipāta yoga is found in VJ, Yajuṣa recension, vv. 19,26. (But

according to Sudhakara Dvivedi's edition with Sanskrit commentary of Jyotiṣa Vedāṅgam,[50] the relevant verses are eighteen and twenty-six). It is however worthy of note that in AJ, only four aṅgas (limbs) viz. tithi (lunar day), nakṣatra (asterism), karaṇa (half-tithi) and muhūrta (1 muhūrta = 48 minutes) are found.[32]

Besides, it is worthy of note that an explicit reference to vyatīpāta yoga is found in Jyotiṣa Karaṇḍaka (= JK), a Jaina work which is, a according to K.S. Raghavan,[51] supposed to have been written in 514 A.D. as a guide to Sūrya Prajñapti and according to N.C. Shastri,[52] assigned to 300-400 B.C. on the basis of linguistic survey ; belike the work belongs to a period round about the advent of Christian era (see 1.2). In this context, JK verse 291 states as :[53]

> *i.e.* "In a yuga (five-year-cycle), divide the sum of number of ayanas of sun and moon by two the quotient will be the number of vyatīpatas in the yuga."

The number of vyatīpātas in a five-year-cycle can easily be computed as follows :

There are ten ayanas of sun and 134 ayanas of moon in a five-year cycle. So the sum of their ayanas becomes 144 which on division by two gives seventy-two as the number of vyatīpātas in a five-year-cycle.

This result suggests that the author of JK was in possession of the notion of vyatīpāta (equal declinations of sun and moon occupying different ayanas). Thus T.S. Kuppannashastri's views[31] about the first occurrence of vyatīpāta in Paitāmaha Siddhānta are questionable.

But any account of Vaidhṛti or other yogas (combinations) is not found in JK or any other Jaina canonical text extant these days. It appears that some relevant texts of Jaina canon might have become extinct these days. Still more investigations are to be made in this field.

6.7. NAKṢATRAS (ASTERISMS)

Forebearance in moon's (motion) bears cognizance of

star-groups (see Yogaloka, verse 132). Moon's motion has a close relation with nakaṣtras known as lunar mansions of the Hindus. However there is a diversity of opinions about Hindu origin of nakṣatras. But we shall restrict ourselves to the study of nakṣatras (asterisms) as described in Jaina canonical works.

(a) NUMBER OF STARS OF NAKṢATRAS (Asterisms)

According to equal amplitude system of twenty-seven nakṣatras (asterisms), each nakṣatra (asterism) has a zodiacal stretch of 13°20'. However, Jainas had an unequal amplitude system of twenty-eight nakṣatras (asterisms) (see 2.3).

There are twenty-eight nakṣatras (asterisms or lunar mansions of Hindus) and abhijit (α Lyrae) tops their list. Every nakṣatra is identified by the number of tārās (stars) associated with it and its apparent natural star-figure called Sansthāna (existence). The number of stars of various nakṣatras are stated thus : (Quotation No. 6.7-1).

"1. Abhijit nakṣatra (asterism) has 3 stars	(SVS. 3, TSS. 227)
2. Śravaṇa nakṣatra has 3 stars	(SVS. 3, TSS. 227)
3. Dhaniṣṭha nakṣatra has 5 stars	(SVS. 5, TSS. 473)
4. Śatabhiṣa nakṣatra has 100 stars	(SVS. 100)
5. Pūrvābhādrapada has 2 stars	(SVS. 2, TSS. 110)
6. Uttarābhādrapada has 2 stars	(SVS. 2, TSS. 110)
7. Revati nakṣatra (asterism) has 32 stars	(SVS. 32)
8. Aśvinī nakṣatra has 3 stars	(SVS. 3, TSS. 227)
9. Bharaṇī nakṣatra has 3 stars	(SVS. 3, TSS. 227)
10. Kṛttika nakṣatra has 6 stars	(SVS. 6, TSS. 539)
11. Rohiṇī nakṣatra has 5 stars	(SVS. 5, TSS. 473)
12. Mṛgaśirṣa nakṣatra has 3 stars	(SVS. 3, TSS. 227)
13. Ārdra nakṣatra has 1 star	(SVS. 1, TSS. 55)
14. Punarvasu nakṣatra has 5 stars	(SVS. 5, TSS. 473)
15. Puṣya nakṣatra has 3 stars	(SVS. 3, TSS. 227)
16. Āśleṣa nakṣatra has 6 stars	(SVS. 6, TSS. 539)
17. Maghā nakṣatra has 7 stars	(SVS. 7, TSS. 589)
18. Pūrvāphālguṇī nakṣatra has 2 stars	(SVS. 2, TSS. 110)
19. Uttarāphālguṇī has 2 stars	(SVS. 2, TSS. 110)

20. Hasta nakṣatra has 5 stars	(SVS. 5, TSS. 473)
21. Citrā nakṣatra has 1 star	(SVS. 1, TSS. 55)
22. Svāṭi nakṣatra has 1 star	(SVS. 1, TSS. 55)
23. Viśākha nakṣatra has 5 stars	(SVS. 5, TSS. 473)
24. Anurādhā nakṣatra has 4 stars	(SVS. 4, TSS. 386)
25. Jyeṣṭhā nakṣatra has 3 stars	(SVS. 3)
26. Mūla nakṣatra has 11 stare	(SVS. 11)
27. Pūrvaṣādhā nakṣatra has 4 stars	(SVS. 4, TSS. 386)
28. Uttarāṣāḍhā nakṣatra has 4 stars	(SVS. 4, TSS. 384)

That is, (the number of stars of various nakṣatras are given below) :

3, 3, 5, 100, 2, 2, 32, 3, 3, 6, 5, 3, 1, 5, 3, 6, 7, 2, 2, 5, 1, 1, 5, 4, 3, 11, 4, 4, (JP. 7.6, SP. 10.9)

According to JS. 158, total number of nakṣatras (asterisms) from Revati (ζ Piscium) to Jyeṣṭha (α Scropii) is ninty-seven. But according to SVS. 4 and TSS. 384, Anurādhā (δ Scorpii) has five stars instead of four ; and therefore the above total becomes ninety-eight. It is explicitly stated in SVS. 98 as : (QuotationNo. 6.7-2).

"There are ninty-eight stars of nineteen nakṣatras (asterisms) from Revati (ξ Piscium) upto Jyeṣṭhā (α Scorpii)."

Therefore it shows that the number four or five of stars of Anurādhā (δ scorpii) nakṣatra was disputed among the authors (or the compilers of present recensions) of JS, and SVS and TSS. This suggests that various texts of Jaina canonical literature might belong not necessarily to the same author.

(b) SANSTHĀNAS (Existences) OF NAKṢATRAS (Asterisms)

Different star-groups of various nakṣatras were speculated to form their different sansthānas (existences) or star figures. In this context, JP. 7 states : (Quotation No. 6.7-3).

"What is the shape of Abhijit (α Lyrae) out of the twenty-eight nakṣatras (asterism) ? (His) shape is Gośirṣāvali.

That is (in case of all the nakṣatras, the shapes are given as follows) :

(1) Gośirṣavali, (2) Kasara, (3) Śakunapiñjara, (4) Puṣpopacāra, (5-6) Vāpi, (7) Naukā, (8) Aśvaskandha, (9) Bhaga, (10) Kṣurādhārā, (11) Śakaṭoddi, (12) Mrgaśirṣāvali, (13) Rudhirabindu, (14) Tulā, (15) Vardhamānaka, (16) Patākā, (17) Prakāra, (18-19) Paryaṅka, (20) Hasta, (21) Mukhapuṣpa, (22) Kīlaka (23) Dāmani, (24) Ekāvalī, (25) Gajadanta (26) Vṛścikalāgūla, (27) Gajavikrama, (28) Sinhaniṣīdana."

This is also explicitly stated in SP. 10.9.

It is worth mentioning here that people who gazed at the skies in ancient times believed that they could see the shape of animals and they traced out in the stars in spite of the fact that the stars in a constellation do not belong to any actual group in space but may be far apart.[28] It is long before astronomy had any existence as a science that the fanciful mind with the charm and beauty of the stars in the dark robe of night was led to recognise on the celestial concave the emblems of terrestrial objects.[29] So the nomenclature of sansthānas or star-figures of twenty-eight nakṣatras (asterisms) has its own significance and it depicts an earlier stage in the history of identification of stars.

(c) **GOTRAS (sub-castes) of NAKṢATRAS (Asterisms)**

All the naksatras have their different gotras (literally, sub-castes). The gotras of nakṣatras are stated in JP. 7.6 as : (Quotation No. 6.7-4).

"Of the twenty-eight nakṣatras (asterisms) what is the gotra (sub-caste) of Abhijit (α Lyrae) ?

(Abhijit or α Lyrae has) Maudgalayana gotra (sub-caste).

That is, (the gotra or sub-castes of all the nakṣatra are given as under) :

(1) Maudgalayana, (2) Saṅkhyāyana, (3) Agrabhāva,
(4) Kannilāyana, (5) Jātukarna, (6) Dhanañjaya,
(7) Pusyāyana, (8) Āśvāyana, (9) Bhārgaveśa,
(10) Agniveśya, (11) Gautama, (12) Bhārdvaja,
(13) Lauhityāyana, (14) Vāsiṣṭha, (15) Avamajjāyana,
(16) Mandvyāyana, (17) Piṅgāyana, (18) Govallayana,
(19) Kāśyapa, (20) Kauśika, (21) Dārbhāyana,

(22) Cāmaracchāyana, (23) Śuṅgāyana, (24) Golavyāyana,
(25) Cikitsāyana, (26) Kātyāyana, (27) Bābhravyāyana,
(28) Vyāghrapṛtya."

This is also explicitly stated in the SP. 10.15.

It seems as if the concept of gotra (sub-caste) was developed to interpret certain peculiarities of a nakṣatra, probably used for some astrological purposes.

(d) **LORDS OF NAKṢATRAS (Asterisms)**

All the nakṣatras have their respective lords. In this context, JP. 7.4 states : (Quotation No. 6.7-5)

"Of the twenty-eight nakṣatra (asterisms) who is the lord of Abhijit (α Lyrae) ? (His Lord) is Brahmā. Viṣṇu is the lord of Śravaṇa (α Aquilae) nakṣatra. Vasu is the lord of Dhaniṣṭhā (β Delphini). Likewise, the list of lords (of nakṣatras or asterisms) is as follows :

(1) Brahmā, (2) Viṣṇu, (3) Vasu, (4) Varuṇa, (5) Aja,
(6) Abhivṛdhi, (7) Pūṣā, (8) Aśva, (9) Yama, (10) Agni,
(11) Prajāpati, (12) Soma, (13) Rudra, (14) Aditi,
(15) Bṛhaspati, (16) Sarpa, (17) Pitra, (18) Bhaga,
(19) Aryama, (20) Savitā, (21) Tvaṣṭā, (22) Vāyu,
(23) Indrāgni, (24) Mitra, (25) Indra, (26) Nairrata,
(27) Ap, (28) Viśva."

This is also explicitly stated in SP. 10.12.

Besides, it is a common belief among Indian astrologers that qualities of nakṣatras (asterisms) and their respective lords are common but how these qualities are determined we have no clue so for.[31] According to Maxmuller, rāśi (sign) gods are Babylonian, but nakṣatra (asterism) gods are Indian.[36] This suggests Vedic origin of nakṣatras (asterisms) and thus Biot's[37] views about Chinese origin of nakṣatras (asterisms) are questionable. However, the mystery of relation between nakṣatras and their respective gotras (sub-castes) and lords is yet to be unearthed.

The list of nakṣatras (asterisms), their numbers of tārās (stars), sansthānas (existences or star figures), gotras (sub-castes) and lords is shown in table (6.7-1).

TABLE 6.7-1

TABLE OF NAKṢATRAS (ASTERISMS), THEIR NUMBERS OF TĀRĀS (STARS), SANSTHĀNAS (EXISTENCES OR STAR FIGURES) GOTRAS (SUB-CASTES) AND LORDS

Sr. No.	*Nakṣatra (asterism)*	*No. of tārās (stars)*	*Sansthāna (existence of star figure)*	*Gotra (sub-caste)*	*Lord*
	1	2	3	4	5
1.	Abhijit (α Lyrae)	3	Gośīrṣāvali	Maudgalayana	Brahmā
2.	Śravaṇa (α Aquilae)	3	Kasāra	Saṅkhyāyana	Viṣṇu
3.	Dhaniṣṭhā (β Delphini)	5	Śakunapiñjara	Agrabhāva	Vasu
4.	Śatabhiśā (λ Aquarii)	100	Puṣpopacāra	Kannilāyana	Varuna
5.	Pūrvābhādrapada (α Pegasi	2)	Vapi	Jātukarna	Aja
6.	Uttarabhadrapada (γ Pegasi)	2)		Dhanañjaya	Abhivṛdhi
7.	Revatī (ξ Piscium)	32	Naukā	Puṣyāyana	Pūṣa
8.	Aśvinī (β Arietis)	3	Aśvaskandha	Aśvāyana	Aśva
9.	Bharaṇī (41 Arietis)	3	Bhaga	Bhārgaveśa	Yama
10.	Kṛttikā (η Tauri)	6	Kṣurādhārā	Agniveśya	Agni
11.	Rohiṇi (α Tauri)	5	Śakṭoddhi	Gautama	Prajāpti
12.	Mṛgaśirṣa (λ Orionis)	3	Mṛgaśirṣavali	Bhardvaja	Soma

1	2	3	4	5
13. Ārdrā (α Orionis)	1	Rudhirabindu	Lauhityāyana	Rudra
14. Punarvasu (β Geminorum)	5	Tulā	Vāsiṣṭha	Aditi
15. Puṣya (δ Cancri)	3	Vardhamānaka	Avamajjāyana	Bṛhaspati
16. Aśleṣā (ε Hydrae)	6	Patākā	Mandvyāyana	Sarpa
17. Maghā (α Leonis)	7	Prākāra	Piṅgāyana	Pitra
18. Pūrvāphālguṇi (δ Leonis	2)	Paryaṅka	Govallayana	Bhaga
19. Uttarāphālgunī (β Leonis)	2)		Kāśyapa	Aryama
20. Hasta (δ Corvi)	5	Hasta	Kauśika	Savitā
21. Citrā (α Virginis)	1	Mukhapuṣpa	Dārbhayana	Tavaṣṭā
22. Svāti 'α Bootis)	1	Kīlaka	Cāmaracchāyana	Vāyu
23. Viśākhā (α Libra)	5	Dāmini	Suṅgāyana	Indrāgni
24. Anurādhā (δ Scorpii)	4 or 5	Ekāvalī	Golavyāyana	Mitra
25. Jyeṣṭhā (α Scorpii)	3	Gajadanta	Cikitsāyana	Indra
26. Mūla (λ Scorpii)	11	Vṛścikalāgūla	Kātyāyana	Nairrata
27. Pūrvāṣāḍhā (δ Sagittarii)	4	Gajavikrama	Bābhravyāyana	Ap
28. Uttarāṣāḍhā (σ (Sagittarii)	4	Sinhaniṣīdana	Vyāghrapātya	Viśva

6.8 LUNAR CONJUNCTIONS WITH NAKṢATRAS (ASTERISMS) ON SYZYGIES

The epoch of lunar conjunction with sun is denoted as a syzygy, viz. amāvasyā (new-moon-day) and pūrṇimā (full-moon-day) There is a twelve-fold nomenclature of pūrṇimās (full-moon-days) and also of amāvasyās (new-moon-days). In this context, JP.9.10 states : (Quotation No. 6 8-1)

i.e. "There are twelve pūrṇimās (full moons) (and) amāvasyās (new moons) viz. Śrāviṣṭhī, Prauṣṭhapadī, Āśvinī, Kārttiki, Mārgaśīrṣakī, Pauṣī, Māghī, Phālguṇī, Caitrī, Vaiśākhi, Jyeṣṭhāmūli, (and) Aṣāḍhī."

This is also explicitly stated in SP.10.6.

The various nakṣatras (asterism) which combine with moon at these syzygies are also stated in some Jaina texts. JP. 9.11-16 states as : (Quotation No. 6.8-2).

i.e. "How many nakṣatras (asterisms) combine (with moon) Śrāviṣṭhī pūrṇimā (full moon day) ? There nakṣatras (asterisms) combine, viz Abhit (α Lyrae), Śravaṇa (α Aquilae) (and) Dhaniṣṭhā (β Delphini).

Prauṣṭhapadī pūrṇimā... ... ...3 nakṣatras... ... ...Śatabhiṣā (λ Aquarii), Pūrvābhādrapadā (α Pegasi) (and) Uttarābhādrapada (γ Pegasi).

Āśvinī pūrṇimā.......2 nakṣatras......Revatī (ξ Piscium) (and) Aśvinī (β Arietis).

Kārttikī pūrṇimā... ...two (nakṣatras), (viz) Bharaṇī (41 Arietis) Kṛttikā (η Tauri).

Mārgaśirṣaki pūrṇimā, two, Rohiṇi (α Tauri), Mṛgaśīrṣa (λ Orions).

Pauṣī (pūrṇimā), three-Ārdrā (α Orionis), Punarvasu (β Geminorum), Puṣya (δ Cancri).

Māghī (pūrṇimā), two-Āśleṣā (ϵ Hydrae), Maghā (α Leonis)

Phālguṇī (pūrṇimā), two-Pūrvāphālguṇī (δ Leonis), Uttarā phālguṇī (β Leonis).

Caitri (pūrṇimā), two-Hasta (δ Corvi), Citrā (α Virginis)

Vaiśākhi (pūrṇimā), two-Svāti (α Bootis) Viśākhā (α Libra)

Jyeṣṭ hāmūli (pūrṇimā), three Anurādhā (δ Scorpii), Jyeṣṭhā (α Scorpii), Mūla (λ Scorpii)

Āṣāḍhī (pūrṇimā), two Pūrvāṣāḍhā (δ Sagittarii), Uttarāṣāḍhā (σ Sagittarii).

How many nakṣatras combine (with moon) at Śrāviṣṭhi amāvasyā ? Two nakṣatras combine, viz. Aśleṣā (ε Hydrae) (and) Maghā (α Leonis) Prauṣṭhapadī amāvasyā, two-Pūrvāphālgunī (δ Leonis) Uttarāphālguṇī (β Leonis).

Āśvinī (amāvasyā), two-Hasta (δ Corvi), Citrā (α Virginis)

Kārttikā (amāvasyā), two-Svāti (α Bootis) Viśākhā (α Libra)

Mṛgaśīrṣakī (amāvasyā), three-Anurādhā (δ Scorpii) , Jyeṣṭhā (α Scorpii), Mūla (λ Scorpii)

Pauṣī (amāvasyā), two-Pūrvāṣāḍhā (δ Sragittarii), Uttarāṣāḍhā (σ Sagittarii)

Māghī (amāvasyā), three-Abhijit (α Lyrae), Śravaṇa (α Aquilae), Dhaniṣṭhā (β Delphini)

Phālgunī (amāvasyā), three-Śatabhiṣā (λ Aquarii), Pūrvābhādrapada (α Pagasi), Uttarābhādrapada (γ Pegasi)

Caitrī (amāvasyā), two-Revati (ξ Piscium), Aśvinī (β Arietis)

Vaiśākhī (amāvasyā), two-Bharaṇī (41 arietis), Kṛttikā (η Tauri)

Jyeṣṭhāmūlī (amāvasyā), two-Rohinī (α Tauri), Mṛgaśīrṣa (λ Orionis)

Āṣāḍhī (amāvasyā), three-Ārdrā (α Orionis), Punarvasu (β Geminorum), Puṣya (δ Cancri).

Where Śrāviṣṭhī Pūrṇimā (full-moon-day) occurs, does Māghī amāvasyā (new-moon-day) occur there ? When Māghī Pūrṇimā (full-moon-day) occurs, does Śrāviṣṭhī amāvasyā (new-moon-day) occur there ?

Yes, where Śrāviṣṭhī Pūrṇimā occurs, it does so.

Where Prauṣṭhapadı Pūrṇimā occurs, does Phālgunī amāvasyā occur there ? Where Phālgunī Pūrṇimā occurs, does Prauṣṭhapadī amāvasyā occur there ?

Yes, it does.

Similarly, (the relation between) Pūrṇimās and amāvasyās should be understood as follows :

"Āśvinī Pūrṇimā and Caitrī amāvasyā, Kārttikī Pūrṇimā and Vaiśākhī amāvasyā, Mṛgaśirṣakī Pūrṇimā and Jyeṣṭhāmūlī amāvasyā, Pauṣī Pūrṇimā and Āṣāḍhī amāvasyā."

This is also explicitly stated in SP. 10-6.

The above data are shown in table (6.8-1).

TABLE 6.8-1

LIST OF NAKṢATRAS THAT COMBINE WITH MOON AT VARIOUS SYZYGIES

Sr. No.	*Pūrnimā (full-moon-day)*	*Amāvasyā (new-moon-day)*	*Nakṣatras (asterisms) that combine with moon*
1.	Śrāviṣṭhī	Māghī	Abhijit (α Lyrae), Śravaṇa (α Aquilae), Dhaniṣṭhā (β Delphini)
2.	Prauṣṭhapadī	Phālguṇī	Śatabhiṣā (λ Aquarii), Pūrvābhādrapada (α Pegasi) Uttarābhādrapada (γ Pegasi)
3.	Āśvinī	Caitrī	Revatī (ξ Piscium) Aśvinī (β Arietis)
4.	Kārttikī	Vaiśākhī	Bharaṇī (41 Arietis), Kṛttikā (η Tauri)
5.	Mṛgaśirṣakī	Jyeṣṭhāmūlī	Rohiṇī (α Tauri), Mṛgaśirṣa (λ Orionis)
6.	Pauṣī	Āṣāḍhī	Ārdrā (α Orionis), Punarvasu (β Geminorum), Puṣya (δ Cancri)
7.	Māghī	Śrāviṣṭhī	Āśleṣā (ε Hydrae), Maghā (α Leonis)

8.	Phālguṇī	Prauṣṭhapadī	Pūrvāphālguṇī (δ Leonis), Uttarāphālguṇī (β Leonis)
9.	Caitrī	Āśvinī	Hasta (δ Corvi), Citrā (α Virginis)
10.	Vaiśākhī	Kārttikī	Svātī (α Bootis), Viśākhā (α Libra)
11.	Jyeṣṭhāmūlī	Mṛgaśīrṣakī	Anurādhā (δ Scorpii), Jyeṣṭhā (α Scorpii), Mūla (λ Scorpii)
12.	Āṣāḍhī	Pauṣī	Pūrvāṣāḍhā (δ Sagittarii), Uttarāṣāḍhā (σ Sagittarii)

Thus it is evident from table (6.8-1) that each pūrṇimā (full-moon-day) as regards its occurrence corresponding to lunar conjunction with nakṣatras (asterisms) has a reciprocal amāvasyā (new-moon-day), e. g. Śraviṣṭhi pūrṇimā (amāvasyā) and Māghi amāvasyā (pūrṇimā) occur in the same region among the stars.

Besides it is obvious by inspection (see table 6 8-1) that the name of the month is called after the name of nakṣtra (asterism) where or in whose specific neighbourhood moon is posited on pūrṇimā or full moon day of that month e.g. moon combines with Śravaṇa (α Aquilae) or its specific neighbourhood on the Śrāviṣṭhī pūrṇimā (full-moon day of the month of Śrāvaṇa) whereras Śrāviṣṭhī amāvasyā occours where Māghī pūrṇimā (full-moon day of the month of Māgha) occurs. Probably to perpetuate this mode of grouping of nakṣatras (asterisms) Jainas divided all nakṣatras (asterisms) into three classes, viz. kula nakṣtra (category asterism), upakulanakṣatra (sub-category asterism) and kulopakula nakṣatra (sub-sub-category asterism). In this context, SP. 10. 5 states : (Quotation No. 6.8-3)

There are twelve kulas (categories) viz.

(1) Dhaniṣṭhā kula, (2) Uttarābhādrapada kula, (3) Aśvinī kula, (4) Kṛttikā kula, (5) Mṛgaśīrṣa kula, (6) Puṣya kula, (7) Maghā kula, (8) Uttarāphālguṇī kula, (9) Citrā kula, (10) Viśākhā kula (11) Mūla kula, (12) Uttarāṣāḍhā kula.

(1) Śravaṇopakula, (2) Pūrvābhādrapadopakula, (3) Revatī upakula, (4) Bharaṇī upakula, (5) Rohiṇī upakula, (6) Punarvasu upakula, (7) Āśleṣopakula, (8) Pūrvāphālguṇī upakula, (9) Hastopakula, (10) Svāti upkula, (11) Jyeṣṭhopakula, (12) Pūrvāṣāḍhopakula.

There are four kulopakulas (sub-sub-categories), viz.

(1) Abhijit kulopakula, (2) Śatabhiṣā kulopakula, (3) Āṛdrā kulopakula, (4) Anurādha kulopakula."

This is also explicitly stated in the JP. 9.9.

It may be noted by inspection from table (6.8.-1) that the total zodiacal arc of nakṣatras (asterisms) associated with any pūrṇimā (full-moon-day) has been specified such that its upper limit (maximum angular distance from beginning of Abhijit i. e. α Lyrae) has been marked by kula nakṣatra (category asterism) and the lower limit (minimum angular distance from beginnig of Abhijit i.e. α Lyrae) by upakula nakṣatra (sub-category asterism) or by kulopakula nakṣatra (sub-sub-category asterism) if it occurs there (see table 6.8-2.)

TABLE 6.8-2

CLASSIFICATION OF KULA (CATEGORY), UPAKULA (SUB-CATEGORY) AND KULOPAKLA (SUB-SUB-CATEGORY) NAKṢATRAS ASSOCIATED WITH DIFFERENT SYZYGIES

Sr. No.	Pūrṇimā (amāvasyā)	Naksatras that combine with moon (see table 6.8-1)		
		Kulopakula (sub-sub-category)	Upakula (sub-category)	Kula (category)
1.	Śrāvisthī (Māghī)	Abhijit (α Lyrae)	Śravaṇa (α Aquilae)	Dhaniṣṭhā (β Delphini)
2.	Prauṣṭhapadī (Phālguṇī)	Śatabhiṣā (λ Aquarii)	Pūrvābhādrapada (α Pegasi)	Uttarābhādrapada (γ Pegasi)
3.	Āśvinī (Caitrī)		Revatī (ζ Piscium)	Aśvinī (β Arietis)

4.	Kārttikī (Vaiśākī)		Bharaṇī (41 Arietis)	Kṛttikā (η Tauri)
5.	Mṛgaśīrṣakī (Jyeṣṭhāmūlī)		Rohiṇī (α Tauri)	Mṛgaśīrṣa (λ Orionis)
6.	Pauṣī (Āṣāḍhī)	Ārdrā (α Orionis)	Punarvasu (β Geminorum)	Puṣya (δ Cancri)
7.	Māghī (Śrāviṣṭhī)		Āśleṣā (ε Hydrae)	Maghā (α Leonis)
8.	Phālguṇī (Prauṣṭhapadī)		Pūrvāphālguṇī (δ Leonis)	Uttarāphālguṇī (β Leonis)
9.	Caitrī (Āśvinī)		Hasta (δ Corvi)	Citra (α Virginis)
10.	Vaiśākhī (Kārttikī)		Svāti (α Bootis)	Viśākhā (α Libra)
11.	Jyeṣṭhāmūlī (Mṛgaśīrṣakī)	Anurādhā (δ Scorpii)	Jyeṣṭhā (α Scorpii)	Mūla (λ Scorpii)
12.	Āṣāḍhī (Pauṣi)		Pūrvāṣāḍhā (δ Sagittarii	Uttarāṣāḍhā (σ Sagittarii)

Evidently the combinations of kula, upakula and kulopakula with any syzygy are said to be made if the respective kula, upakula and kulopakula nakṣatras (asterisms) are associated with that syzygy (see table 6.8-2). This is also evident from an example stated in JP.9.12 as : (Quotation 6.8-4)

"Does Śrāviṣṭhī pūrṇimā combine with a kula, upakula and kulopakula ?

Kula combines, upakula combines, kulopakula combines. In combining with kula, Dhaniṣṭhā (β Delphini) nakṣatra (asterism) combines; in combining with upakula, Śravaṇa (α Aquilae) nakṣatra (asterism) combines: in combining with kulopakula, Abhijit (α Lyrae) nakṣatra (asterism) combines."

This is also explicity stated in SP. 10.6.

Besides the positions of full moons and new moons with respect to nakṣatras are also stated in SP.10.22. 16-20 as : (Quotation No. 6.8-5)

"Which nakṣatra (asterism) is combined with moon at the first pūrṇimā (full moon day) of five samvatsaras (five-year cycle) ? The answer is Dhaniṣṭhā (β Delphini). Balance of Dhaniṣṭhā (β Delphini) is $3\frac{19}{62}+\left(\frac{1}{62}\times\frac{1}{67}\times\frac{65}{1}\right)$ muhūrtas.

.........second pūrṇimā,...........uttarābhādrapada (γ pegasi). Balance of Uttarābhādrapada is $27\frac{14}{62}+\left(\frac{1}{62}\times\frac{1}{67}\times\frac{64}{1}\right)$muhūrtas.

...third pūrṇimā,.........Aśvinī (β Arietis).

Balance of Aśvinī is $21\frac{9}{62}+\left(\frac{1}{62}\times\frac{1}{67}\times\frac{63}{1}\right)$ muhūrtas.

.. twelfth pūrṇimā,...........Uttarāṣāḍhā (σ Sagittarii). Balance of Uttarāṣāḍhā is $26\frac{26}{62}+\left(\frac{1}{62}\times\frac{1}{67}\times\frac{54}{1}\right)$ muhūratas.

...the last sixty-second pūrṇimā,...Uttarāṣāḍhā (σ Sagittarri). Ending moments of Uttarāṣādhā.

...first amāvasyā............Aśleṣā (ϵ Hydrae). Balance of Aśleṣā is $1\frac{40}{62}+\left(\frac{1}{62}\times\frac{1}{67}\times\frac{66}{1}\right)$ muhūrtas.

.........second amāvasyā......... Uttarāphālguṇī (β Leonis). Balance of Uttarāphālguṇī is $40\frac{35}{62}+\left(\frac{1}{62}\times\frac{1}{67}\times\frac{65}{1}\right)$ muhūrtas.

...third amāvasya.........Hasta(δ Corvi).

Balance of Hasta is $4\frac{30}{62}+\left(\frac{1}{62}\times\frac{1}{67}\times\frac{64}{1}\right)$ muhūratas.

...twelfth amāvasyā.........Ārdrā (α Orionis).

Balance of Ārdrā is $4\frac{10}{62}+\left(\frac{1}{62}\times\frac{1}{67}\times\frac{54}{1}\right)$ muhūrtas.

...the last sixty-second amāvasyā...punarvarsu (β Geminorum). Balance of Punarvasu is $22\frac{46}{62}$ muhūrtas."

Obviously the sixty-second pūrṇimā (full-moon-day) ends with the ending moments of Uttarāṣāḍhā (σ Sagittarii) or the beginning of Abhijit (α Lyrae) wherefrom commences the beginning of five-year-cycle. The scale of zodiacal circumference also begins from the beginning point of Abhijit (α Lyrae) nakṣatra (asterism) (see 2.3). The above positions of moon among nakṣtras can easily be computed as follows :

$$1 \text{ lunar month} = 29\frac{32}{62} \text{ days or } 885\frac{30}{62} \text{ muhūrtas}$$

$$(\because 1 \text{ day} = 30 \text{ muhūrtas})$$

Therefore the first pūrṇimā (full moon day) occurs $885\frac{30}{62}$ muhūrtas or (expunging integral multiples of $819\frac{27}{67}$ muhūrtas of a circle) $66\frac{336}{62\times67}$ muhūrtas after the beginning point of Abhijit (α Lyrae) nakṣatra (asterism) or $3\frac{19}{62}+(\frac{1}{62}\times\frac{1}{67}\times\frac{65}{1})$ muhūrtas balance of Dhaniṣṭhā (β Delphini) (see table 2.3-1). Moreover, evidently the longitude of full moon advances by $66\frac{336}{62\times67}$ muhūrtas a lunar month.

The longitude of the first new moon occurs $442\frac{46}{62}$ muhūrtas (half the length of a lunar month) after the occurrence of sixty-second pūrṇimā (full-moon-day). Thus expunging zodiacal stretches of some nakṣatras (asterisms) beginning from Abhijit

(α Lyrae), we find that it occurs at $1\frac{40}{62} + (\frac{1}{62} \times \frac{1}{67} \times \frac{66}{1})$ muhūrtas balance of Āśleṣā (ε Hydrae).

Likewise, positions of all the sixty-two full moons and sixty-two new moons in a five-year cycle can easily be computed by advancing the longitude of full moon and that of new moon by $66\frac{336}{62 \times 67}$ muhūrtas a lunar month respectively.

Jaina texts have also given the corresponding positions of sun which may be easily computed from the fact that the longitude of sun on amāvasyā (new-moon day) is the same as that of moon because sun and moon are in conjunction on amāvasyā (new-moon-day) and longitude of sun on pūrṇimā (full-moon-day) is $442\frac{46}{62}$ muhūrtas (half the length of a lunar month) behind that of moon, because moon is in opposition with sun at that time.

6.9 *THE JAINA FIXED CALENDER*

In the light of foregoing discussion in this chapter, it is obvious that Jainas had a five-year fixed lunar and solar ephemerides. A five-year cycle contains.

60 solar months = 62 lunar months

$\therefore$ 1 solar month $= \frac{31}{30}$ lunar months $= (1 + \frac{1}{30})$ lunar months.

Thus the intercalary remainder increases by $\frac{1}{30}$ lunar month a solar month and it becomes one lunar month after thirty solar months. Therefore the thirty-first lunar month is inserted as an intercalary month and the third Samvatsara (year) becomes abhivardhana samvatsar a ('lustfully increased year' denoting a lunar year with an intercalary month). Similarly the fifth samavatsara also becomes an intercalary year. Jainas five-year fixed Calendar is produced in table (6.9-1).

However, Sohan Lal[34] has also made a Jaina almanac based on Jaina five-year fixed calendar but Veli Ram Jaini[35] has made a severe criticism of it; among serveral points of objection to some inaccuracies which have their provenance into the inaccurate length of year etc., it is worth mentioning that it is not known why Sohan Lal calls laukika (prevalent) Āṣāḍha (fourth month of Hindu calendar) as Jaina Śrāvaṇa (fifth month of Hindu calendar).[35] However it may be remarked that Hindus are also accustomed to count a solar year with Vaiśākha (second month of Hindu calendar commencing from lunar Caitra as the first month) as the first month commencing with sun's entry into Meṣa (sidereal Aries sign). Thus it seems contemplable that Sohan Lal might have committed an error in calling Vaiśākha a month corresponding to first laukika (prevalent) month of Jaina five-year fixed calendar ; so the fourth laukika (prevalent) month Āṣāḍha might have been mistaken for Śrāvaṇa (fifth month of Hindu calendar).

Now we give below a note on the inaccurate procedure of intercalation in Jaina five-year fixed calendar. Looking at table (6.9-1), it may easily be discerned that nakṣatras (asterisms) at twenty-sixth and twenty-seventh pūrṇimās (full-moon days) belong to the group of nakṣatras associated with Prauṣṭhapadī pūrṇimā i.e. full-moon day of sixth lunar month of Hindu calendar (see table 6.8-1). The nakṣatra at twenty-eighth pūrṇimā is Aśvinī (β Arietis) which is associated with Aśvinī pūrṇimā (full-moon-day of seventh lunar month of Hindu calendar) following Prausthapadī pūrṇimā; whereas the nakṣatra at twenty-ninth pūrnimā is Rohiṇī (α Tauri) which is associated with Mṛgaśirṣakī pūrṇimā (full-moon-day of ninth lunar month of Hindu calendar) following Kārttikī pūrṇimā (full-moon-day of eighth lunar month of Hindu calendar) (see table 6.8-1). Thus it is evident that no pūrṇimā (full-moon-day) occurs at any nakṣatra associated with Kārttikī pūrnimā (full-moon day of eighth lunar month of Hindu calendar) and consequently no month by the name Kārttika (eighth lunar month of Hindu calendar) occurs in third samvatsara (year) of Jaina five-year fixed calendar whereas two months by the same name Prauṣṭhapada (sixth lunar month of Hindu calendar) occur during this period The second Prauṣṭhapada may conveniently be called intercalary

Prausṭhapads month and the Kārttika called decayed month. Howevor according to modern notions,[44] a lunar month becomes an intercalary month if no saṅkrānti (solar ingress into a rāśi or sidereal sign) occurs in it and a lunar month with two saṅkrāntis becomes a decayed month. These modern notions should not be intertangled with the notions of intercalary and decayed months as referred to above in context of Jaina five-year fixed calendar. With this framework of mind, other intercalary and decayed months in Jaina five-year fixed calendar may conveniently be sorted out by inspection from table (6.9-1) and table (6.8-1). They are given in table (6.9-2).

TABLE 6.9-2

LIST OF INTERCALARY AND DECAYED LUNAR MONTHS IN JAINA FIVE-YEAR FIXED CALENDAR

Sr. No.	*Sr. No. of samvatsara (year)*	*Intercalary month (Sr. No. of month in five-year cycle)*	*Decayed month (Sr. No. of month in five-year cycle)*
1.	Third	Prausṭhapada (27)	Kārttika (28)
		Pauṣa (31)	Māgha (32)
		Phālguṇa (33)	Vaiśākha (35)
		Jyeṣṭhamūla (36)	
2.	Fifth	Prausṭhapada (52)	Āśvina (52)
		Pauṣa (56)	Māgha (56)
		Āṣāḍha (62)	

In all there are seven intercalary months and five decayed months resulting intercalation of two months (thirty-first and sixty-second as per Jaina five-year fixed calendar). It may however be noted that intercalary and decayed months vide table (6.9-2) have been determined on the basis of mean motion of moon and unequal amplitude system of nakṣatras (lunar mansions) measured into muhūrtas of arc (see table 2.3—1). Evidently some pūrṇimās will not occur actually at their nakṣatras vide table (6.9—1) but they may occur at their nakṣatras associated with them vide table 6.8-1. Thus it may be contemplated that the classification of nakṣatras

(asterims) into groups associated with different pūrṇimās (full moon days) vide table (6.8—1) was not made in accordance with Jaina five-year fixed calendar as the theory of such classification does not fit the computation of Jaina five-year fixed calendar. Probably the classification of nakṣatras into various groups associated with different syzygies (see table 6.8-1) was made on direct observational basis and theory was perpertuated by further classification of nakṣatras into kula (category), upakula (sub-category) and kulopakula (sub sub-category) nakṣatras associated with various syzygies. This view is also supported by the fact that Jainas had attempted to measure zodiacal stretches of nakṣatras (see 2.3).

On the other hand, it may also be inferred that :

1. In the absence of accurate knowledge about the true motion of moon, Jainas could not frame calender (other than their five-year fixed calendar based on mean motion of moon) such that relation between nakṣatras and different syzygies as depicted in table (6.8-1) may also hold good in all cases.

2. It appears as if Jainas could not work out properly the cycle of intercalation and decay of months (as we have expounded in table 6.9-2) and without caring for any relation between nakṣatras and syzygies (see toble 6.8-1), they on average intercalated two months, viz. thirty-first and sixty-second (see table 6.9-1), as it did not materially influence general mode of their religious life. However regarding the difficulty about the question of a thirteenth month, there is normally no hint if there was any question of a cycle of years and it is possible, as Keith remarks, that the sacrifical rituals rendered, some sort of intercalation needful.[40] So it may be contemplated that Jaina five-year fixed calendar served all their religious purposes whereas exponents of Jaina School of astronomy might have stuck to the relation, albeit inadequately, between nakṣatras and syzygies (see table 6.8-1) for all astronmical purposes.

Besides it may be worth mentioning that Jainas had an empirical notion of decay of nakṣatra months (lunar sidereal

revolutions). In this context, S. P. 1.1.3 states : (Quotation No. 6.8-6).

i.e. "How much does loss of muhūrtas (of nakṣatra month i.e. lunar sidereal revolution) take place ?

The answer is $819\frac{27}{67}$ muhūrtas."

We know that $819\frac{27}{67}$ muhūrtas ($=27\frac{21}{67}$ days) is the length of a nakṣatra month or lunar sidereal revolution (see table 6.2-2) and also that a five-year-cycle contains

62 lunar months = 67 nakṣatra months (lunar sideral revolutions)

Thus five nakṣatra months (lunar sidereal revolutions) are to be intercalated during sixty-two lunar months of five samvatsaras (years) of the Jaina fixed calendar. So one nakṣatra month or $819\frac{27}{67}$ muhūrtas are on average to be intercalated every year. Since an intercalary month is an extra month and not counted among twelve months of an year, so it might have been considerd as lost. Such an empirical notion of loss of a nakṣatra month (or $819\frac{27}{67}$ muhūrtas) should not be confusing with notion of decayed lunar month as implied in the construction of table (6.9-2).

Besides, it is worthy of note that Jaina five-year fixed calendar (see table 6.9-1) is distinguished from VJ calendar[18] in some factors mainly given below :

1. Winter solstice lies in Dhaniṣṭhā in VJ calendar and it lies at the beginning of Abhijt (α Lyrae) in Jaina calendar.

2. Lunar months are amāvasyānta (ending with new moon days) in VJ calendar and pūrṇimānta (ending with full-moon days) in Jaina calendar. The year in VJ calendar commences from first day of lunar bright half of Māgha (eleventh month of Hindu calendar) whereas in Jaina calendar, the year comme-

nces from first day of lunar dark half of Sravaṇa (fifth nonth of Hindu calendar).

3. Longitudes of sun and moon have been measured in terms of nakṣatras only in VJ calendar, but in muhūrtas of arc $\left(819\frac{27}{67}\text{ muhūrtas of arc} = 360^\circ\right)$ starting from zero at the beginning of Abhijit (α Lyrae) nakṣatra in Jaina calendar.

4. According to Vedic calendar, seasons are found to begin with Spring[55] (see TB. 1.1.3.6,7) but according to Jaina calendar, seasons commence with Rainy season with Āṣādha (fourth month of Hindu calendar) as the first month, though the five-year cycle commences with the first day of the dark half of Śrāvaṇa (fith month month of Hindu calendar).

5. In VJ calendar, only twenty-seven nakṣatras (asterisms) are taken into account but Jaina calendrical calculations are based on unequal amplitude system of twenty-eight naksatras, Abhijit (α Lyrae) being the extra nakṣatra and strange enough that it also heads the list of nakṣatras (see 2.3).

6. In VJ calendar, the days were called after the names of nakṣatras,[8] viz. day of Maghā (α Leonis) nakṣatra etc. but in Jaina calendar, the cycle of days was reduced from twenty-seven (the number of nakṣatras according to VJ calendar) to fifteen (the number of days in a parva i.e. lunar half of a month) and the days were called by the ordinal numbers as pratipada day (first day), second day etc. upto fifteenth day.

7. In VJ calendar we find no classification of nakṣatras regarding their conjunctions with moon at various syzygies but we find in Jaina calendar that nakṣatras have been classified into groups specifying different regions among stars where the moon will be posited at various syzygies. Further the nakṣatras associated with any syzygy have been classified as kula (category), upakula (sub-category) and kulopakula (sub-sub-category) nakṣatras.

In the light of foregoing discussion, it seems plausible that Jaina five-year fixed calendar should not be mistaken for VJ five year fixed calendar.

CHAPTER VII

KINEMATICS OF VENUS

7.1 INTRODUCTION

Here a simple probe is rendered into the kinematics of venus moving in different vīthis (lanes) amog the stars. It is revealed that Jainas had some trends towards the study of phenomena of heliacal rising and setting of venus in different parts of lunar zodiac.

Long long ago, the phenomena of heliacal rising and setting of stars were known. The Assyrians had a stellar calendar as decoded from the Kūltepe texts of the nineteenth century B C., which comprised of twelve months including at least two names of these months chosen for astronomical phenomena which occurred every year during the months so named : Tanmatra (heliacal rising was the month of rising of the constellation Canis Major, the principal star of which, Sirius, played an important part in the Assyrian pantheon; Makhur-ili (meeting of the gods) alludes to the conjunction between the moon and the Pleiades prior to the heliacal setting of the latter.[1] According to Rig Veda (i.105.11), ancient Hindus had also identified the heliacal rising of the dog-star (Sirius).[1a]

Apart from the diurnal rising and setting, a star or a planet is said to be heliacally set and risen when it disappears in the sun's glare before conjunction and returns to visibility thereafter. The inferior planets, mercury and venus, become combust twice during their synodic periods. They set in the west a few days before inferior conjunction and rise in the east, and again set in the east some days before superior conjunction and rise in the west. Superior planets like mars, jupiter and saturn always heliacally set in the west and after conjunction the planet moves relatively to the west of sun and heliacally rises as a morning star in the eastern horizon a little befor sunrise.

For heliacal rising of stars and planets on the horizon, sun must be situated a few degrees below horizon so that the sky illumination due to sun may become so diminished as essential for visibility of the particular star or the planet. Although stars upto the sixth magnitude become visible at the close of the astronomical twilight (sun 18° below the horizon) in the evening till the beginning of the astronomical twilight in the morning, yet the stars fainter than magnitude 4.0 are hardly visible on horizon because of greater density and thickness of atmosphere near the horizon during this period. During the period of astronomical twilight (sun not more than 18° below the horizon), the part of sky above the sun is more illuminated than rest of the sky ; consequently the visibility condition (brilliancy of the star) during this period for stars on the horizon diminishes as they are situated nearer to the sun. Besides, in a particular case of the planet venus near its maximum brilliancy, sometimes it becomes visible at a high altitude in a clear sky even during the day time. Moreover, when the geocentric latitude of venus exceeds 6° at the time of geocentric conjunction with sun, it may not then become heliacally invisible for places at very high latitudes, north for north latitudes, and south for south latitudes, and the planet will be visible both in the morning and the evening for a few days.[3]

Besides inferior planets are retrograde during inferior combustion and direct during superior combustion. So the magnitude of relative velocity of an inferior planet (mercury or venus) with respect to sun is equal to the sum or the difference of magnitudes of their respective geocentric velocities during inferior and superior combustions respectively. Consequently venus traverses the arc of combusion (double the arc of visibility of the planet or planet's angular stretch with respect to sun during which the planet remains heliacally invisible) rapidly in inferior combustion than in superior combustion. Besides, venus is nearer to the earth while in inferior combustion than while in superior combustion. Hence magnitude of venus becomes greater in inferior combustion than the same in superior combustion. Consequently the arc of visibility of venus (value of depression of sun below horizon required for the occurrence of phenomena of heliacal rising and setting of venus) is smaller in inferior combustion than the same in superior combustion. However, the eccentricity of orbit

of venus is small, so its magnitude at a particular phenomena (heliacal rising or setting) becomes very nearly the same in every revolution yielding nearly the same value for the arc of visibility necessary for the heliacal rising or setting. A typical table as given by Neugebauer and revised by Schoch is reproduced below :[8]

TABLE 7.1-1

ARC OF VISIBILITY OF VENUS FOR HELIACAL RISING OR SETTING

	Heliacal rising	Reliacal setting
Veus :		
Western horizon		
Direct	5°.8	—
Retrograde	—	5°.2
Eastern horizon		
Retrograde	5°.8	—
Direct	—	5°.9

Evidently the heliacal visibility of venus would be greatly influenced by factors like the brightness of the planet, azimuthal difference between sun and the planet, altitude of the place of observation, intensity of illumination of twilight and atmospheric conditions prevailing at the place. In the light of foregoing discussion it is revealed in the following paragraphs that Jainas had some trends towards kinematical studies of the phenomena of heliacal rising and setting of venus in different parts of lunar zodiac.

7.2. *Concept of Vīthis (Lanes) of Venus*

(a) *Vīthis (Lanes) of Venus*

Venus appears as a morning star or an evening star. The lustre of the capricious goddess of beauty depends upon several factors as mentioned before. The phenomena of gradual diminution of the lustre of venus from its full brilliancy to the state of invisibility and vice veasa[11] very similar to that of moon must have been noticed, albeit inadequately, by the ancient star-gazers. Some alike trends are exhibited in some texts of Jaina canon. Jainas had cognised the phenomena of heliacal rising and setting of venus and they attempted to estimate the average velocities of venus in heliacal combustion in different parts of lunar zodiac. The heliacal combust venus is supposed to move in different vīthis (lanes) among stars. The earliest record in this connection is found in TSS. TSS.9.699 states as : (Quotation No. 7.1-1)

> i.e. "There are nine vīthis (lanes) of venus, viz. haya vīthi (horse lane), gaja vīthi (elephant lane), nāga vīthi (snake lane), vṛṣabha vīthi (bull lane), go vīthi (cow lane), uraga vīthi (reptile lane), aja vīthi (goat lane), mṛga vīthi (deer lane), vaiśvānara vīthi (fire lane)."

The word 'vīthi' literally means a lane. Thus for instance, haya vīthi alludes to the notion that it denotes the zodiacal lane among the stars where venus moves like a haya (horse). We shall later come to this point again.

But slightly a different nomenclature of vīthis is found in BBS.15.45-49 as :[4]

> "nāga vīthi, gaja vīthi, airāvata vīthi (chief elephant lane) vṛṣa vīthi, go vīthi, Jaradgava vīthi (old bull lane), aja vīthi, mṛga vīthi, and vaiśvānara vīthi."

According to VS.7.1-2, mṛga vīthi and aja vīthi interchange their positions and vaiśvānara vīthi is replaced by dahana vīthi (fire lane)[5] which is merely a name variant of the former. A similar account of vīthis (lanes) is found in BTS.9.1 also.[6] The mode of revision in the nomenclature of vīthis (lanes) in due time from TSS to BTS suggests that the phenomena of heliacal rising and setting of venus might have been studied continuously during

this period. However, Varāhamihira (505 A. D.), the celebrated author of BTS, refers to the popular viewppints of others like Kaśyapa, Devala, Garga and Samāsa from the historical point of view but he himself did not understand much of it as he explicitly mentions as : (Quotation No. 7.1-2).

i.e. "Jyotiṣa (astronomy) is an āgama śāstra (sacred scriptural knowledge) uttered through intuition. I know little of it but put forth views of others."

Varāhamihira makes no reference to the Jaina work BBS which exhibits a distinct account of nomenclature of vīthis; probably because he referred to only the viewpoints in vogue at that time and thus this portion of BBS might belong to a period much earlier than Varāhamihira (505 A. D.) lived. It may also be quite probable that Varāhamihira might have not come across the text of BBS which like the Jaina canonical works, might have been preserved in the memory of Jaina monks for a long time before its present recension might have been redacted. This view is upheld by the fact that the work BBS belongs to Bhadrabhāhu who is said to have convened a council of Jaina monks in Pāṭlīputra and had established a fragmentary Jaina canon which was for long time preserved inmemory (see I.1.a). However, it appears that BBS gives the earliest exhaustive account of vīthis (lanes) and it exclusively mentions lengths of arcs of inferior and superior combustions of venus in several vīthis (lanes). In this context, BBS. 7.206-223 states . (Quotation No. 7.1-3).

i.e. "Venus sets in the east and rises in the west.

in vaiśvānara vīthi after 86 days	(BBS.7.206)
in mṛga vīthi after 84 days	(BBS.7.207)
in aja vīthi after 86 days	(BBS.7.208)
in jaradgava vīthi after 75 days	(BBS.7.209)
in go vīthi after 70 days	(BBS.7.210)
in vṛṣa vīthi after 65 days	(BBS.7.211)
in airāvaṇa vīthi after 60 days	(BBS.7.212)
in gaja vīthi after 85 days	(BBS.7.213)
in nāga vīthi after 55 days	(BBS.7.214)

Venus again sets (in the west) and rises in the east,

in vaiśvānara vīthi after 24 days (BBS.7.215)
in mṛga vīthi after 22 days (BBS.7.216)
in aja vīthi after 20 days (BBS.7.217)
in jaradgava vīthi after 17 days (BBS.7.218)
in go vīthi after 14 days (BBS.7.219)
in vṛṣa vīthi after 12 days (BBS.7.220)
in airāvaṇa vīthi after 10 days (BBS.7.221)
in gaja vīthi after 8 days (BBS.7.222)
and in nāga vīthi after 6 days (BBS.7.223)

These data may be put in table (7.1-2).

TABLE 7.1-2

THE BBS NUMBERS OF DAYS FOR WHICH VENUS REMAINS HELIACALLY INVISIBLE IN DIFFERENT VĪTHIS (LANES) AMONG THE STARS

Sr. No.	Names of vīthis (lanes) of Venus	Number of days for which venus remains heliacally invisible during	
		Inferior combustion	Superior combustion
1.	vaiśvānara (fire)	24	86
2.	mṛga (deer)	22	84
3.	aja (goat)	20	86
4.	jaradgava (old bull)	17	75
5.	go (cow)	14	70
6.	vṛṣa (bull)	12	65
7.	airāvaṇa (chief elephant)	10	60
8.	gaja (elephant)	8	85
9.	nāga (snake)	6	55

It seems plausible that the phenomena of heliacal combustion, both superior and inferior, had been keenly studied before BBS was compiled. The length of arc of combustion implicitly associated with different vīthis (lanes) of venus, has been measured in numbers of days for which venus remains invisible therein respectively. It appears that the variations in the time lengths of

arc of combustion have been mainly regarded due to changes in the relative mean velocity of heliacally invisible venus in different parts of the lunar zodiac and such different relative mean velocities of heliacally invisible venus have been relatively compared with some conventionally known velocities like those of haya (horse), nāga (snake) etc.

(b) *ORDER OF VĪTHIS (LANES)*

By inspection (see table 7.1-1) it is evident that order of vīthis (lanes), according to BBS, follows an arrangement of vīthis in the descending order of their numbers of days of heliacal invisibility of venus in inferior combustion. Vaiśvānara vithi tops the list. This order is partly violated in case of heliacal invisibility of venus in superior combustion. By dint of several observational implications of the phenomena of heliacal combustion of venus, it may be envisaged that the phenomena of inferior combustion could be studied more accurately than the phenomena of superior combustion. Thus in order to divulge the secrets of this theory of kinematical studies of venus, it seems plausible to depend more on the data relevant to inferior combustion of venus than on the data of its superior combustion.

Besides, the period of eight years less two days may conveniently be used for venus ; after this period longitude of venus decreases by 2° nearly.[7] This period is equivalent to five synodic periods of venus (synodic period of venus = 583.921 days).[10] So only five vīthis (lanes) occur in an eight-year cycle of venus and their mid points (exact conjunctions of sun and venus) will be located equidistantly along the ecliptic and forming a regular pentagon with an arc length.

$$\hat{s} = \frac{360°}{5} = 72°$$

We may call $\hat{s}$ a mean 'basic interval' or a mean step. This arc $\hat{s}$ is not the distance between consecutive conjunctions in actual order of occurrence of vīthis, which is given by the mean synodic arc.

Now as the regular pentagon of mid points of vīthis of venus retrogrades with an angular velocity of 2° an eight-year cycle of

venus, so any vertex (corresponding to mid-point of a particular vīthi of venus) retrogrades through ā in a period P such that.

$$P = \frac{8}{2^\circ} \bar{a} \text{ years}$$

$$= 288 \text{ years} \quad (\because \bar{a} = 72^\circ)$$

This suggests that venus happens to be again in conjunction with sun at the same place among the stars after a period of 288 years. Consequently cycle of vīthis of venus repeats also. Therefore it seems plausible that the phenomenon of combustion of venus in different regions of lunar zodiac must have been studied for at least 288 years before one might have pondered over the question of classification of vīthis of venus. This leads us to the view that the relevant data as contained in TSS owes its existence to a long tradition of observing the phenomena of heliacal rising and setting of venus, at least a few centuries earlier than TSS was compiled.

(c) *NAKṢATRAS (ASTERISMS) OF DIFFERENT VĪTHIS*

All the twenty-eight nakṣatras (asterisms) have been distributed among all the nine vīthis (lanes). In this context, BBS.15.45-49 states : (Quotation No. 7.1-4).

"Nāga vīthi occurs in Aśvinī, Bharaṇī, Kṛttikā ;
Gaja vīthi occurs in Rohiṇī, Mṛgaśirṣo, Ārdrā ;
Airāvata vīthi occurs in Punarvasu, Puṣya, Āśleṣā ;
Vṛṣa vīthi occurs in Pūrvāphālguṇī, Uttarāphālguṇī, Maghā ;
Go vīthi occurs in Pūrvābhādrapada, Uttarābhādrapada, Revati ;
Jaradgava vīthi occurs in Śravaṇa, Dhaniṣṭhā, Śatabhiṣā ;
Aja vīthi occurs in Hasta, Viśākhā, Citrā, Svāti ;
Mṛga vīthi occurs in Jyeṣṭhā, Mūla, Anurādhā ;
Vaiśvānara vīthi occurs in Pūrvāṣāḍhā, Uttarāṣāḍhā, Abhijit."

Two more different patterns of allocation of nakṣatras (asterisms) to different vīthis (lanes) are found in BTS of Varāhamihira. A comparative picture is shown in table (7.1-3).

TABLE 7.1-3

VĪTHI AND THEIR NAKṢATRAS

Sr. No.	Name of vithi (lane)	Nakṣatras according to Bhadrabāhu	Nakṣatras according to Kasyapa and Devala	Nakṣatras according to Garga, Smāsa and Varāhamihira
1.	nāga (snake)	Aśvinī (β Arietis), Bharaṇī (41 Arietis) Kṛttikā (π Tauri)	Aśvinī, Bharaṇī Kṛttika	Svāti (α Bootis), Bharaṇī, Kṛttikā
2.	gaja (elephant)	Rohiṇī (α Tauri), Mṛgaśirṣa (λ Orionis), Ārdrā (α Orionis)	Rohiṇī, Mṛgaśirṣa, Ārdrā	Rohiṇī, Mṛgaśirṣa, Ārdrā
3.	airāvata (chief elephant)	Punarvasu (β Geminorum), Puṣya (δ Cancri), Aśleṣā (ϵ Hydrae)	Punarvasu, Puṣya, Aśleṣa	Punarvasu, Puṣya, Aśleṣā
4.	vṛṣa (bull)	Maghā (α Leonis), P. phālguṇī (δ Leonis), U. phālguṇī (β Leonis)	Maghā, P. phālguṇi, U. phālguṇi	Maghā P. phālguṇī, U. phālguṇī
5.	go (cow)	P. bhādrapada (α Pegasi) U. bhādrapada (γ Pegasi) Revatī (ξ Piscium)	Hasta (δ Corvi) Citrā (α Virnis) Svāti (α Bootis)	P. bhādrapada U. bhādrapada Revatī, Aśvinī

6.	jaradgava (old bull)	Śravana (α Aquilae) Dhaniṣṭhā (β Delphini) Śatabhiṣā (λ Aquarri)	Viśākhā (α Librae) Anurādhā (δ Scorpii) Jyeṣṭhā (α Scorpii)	Śravaṇa, Dhaniṣṭhā, Śatabhiṣā
7.	aja (goat	Hasta (δ Corvi), Citrā (α Virginis) Svāti, Viśākhā (α Librae)	Śravaṇa (α Aquilae) Dhanisthā (β Delphini) Śatabhisā (λ Aquarii)	Hasta, Citra, Viśākhā
8.	mṛga (deer)	Jyeṣṭhā (α Scorpii) Mūla (λ Scorpii) Anurādhā (δ Scorpii)	Mūla, P. ṣādā (δ Sagittarii) U. sādhā (σ Sagittarii)	Anurādhā, Jyeṣṭhā, Mūla
9.	vaiśvānara (fire)	P. ṣāḍhā (δ Sogittarii) U. ṣāḍhā (σ Sagittarii) Abhijit (α Lyrae)	P. bhādrapada (α Pegasi) U. bhādrapada (γ Pegasi) Revati (ξ Piscium)	P. ṣāḍhā, U. ṣāḍhā

It may be noted that if mṛga vīthi (deer lane) and aja vīthi (goat lane) interchange their places the order of vīthis, according to Kaśyapa and Devala, becomes associated with the nakṣatras in the natural order. This way of distribution of nakṣatras (asterisms) in their natural order among the vīthis arranged in the descending order of their numbers of days of combustion (see table 7.1-1) seems to be more of theoretical interest, for practically it cannot hold good as the number of days of combustion is a complicated function[8] of many factors like latitude of observer, apses of orbit of venus, apses of orbit of earth etc. and especially geocentric latitude of venus (see 7.1).

According to Garga, Smāsa, and Varāhamihira group, the pattern of allocating the nakṣatras (asterisms) to different vīthis (lanes) is almost the same as that of BBS, except that Svāti (α Bootis) is transferred from aja vīthi (goat lane) to nāga vīthi (snake lane), Aśvinī (β Arietis) from nāga vīthi (snake lane) to go vīthi (cow lane). Besides, Abhijit (α Lyrae) is excluded from the list of nakṣatras (asterisms) in BTS. This indicates that Varāhamihira etc., all were the followers of Siddhāntic astronomy wherein only the twenty-seven nakṣatras were held in esteem; and they might have endeavoured to verify the ancient data and consequently the BBS pattern of allocation of nakṣatras to vīthis might have been modified with some alterations. Besides, according to BBS, twenty-eight nakṣatras (asterisms) are distributed in an irregular manner among different vīthis ordered in the sequence of their numbers of days of inferior combustion respectively. It appears that practical observation has an unambiguous bearing upon the relation between vīthis and their nakṣatras during which venus remains heliacally invisible for the number of days associated with the respective vīthis.

Using table (2.3-1), the lengths of the zodiacal intercepts of different vīthis can easily be computed by adding the zodiacal stretches in muhūrtas[9] (see 2.3) of all their respective nakṣatras. For example, according to BBS.

Zodiacal intercept of nāga vīthi (snake lane) = sum of zodiacal stretches of Aśvinī (β Arietis), Bharaṇī (41 Arietis) and Kṛttikā (η Tauri).

$$= 30 + 15 + 30 = 75 \text{ muhūrtas}$$

Rearranging vīthis (see table 7.1-2) in accordance with their nakṣatras juxtaposed in their natural order, zodiacal intercepts of all the vīthis (lanes) and their numbers of days of invisibility of venus in inferior combustion are shown in table (7.1-4).

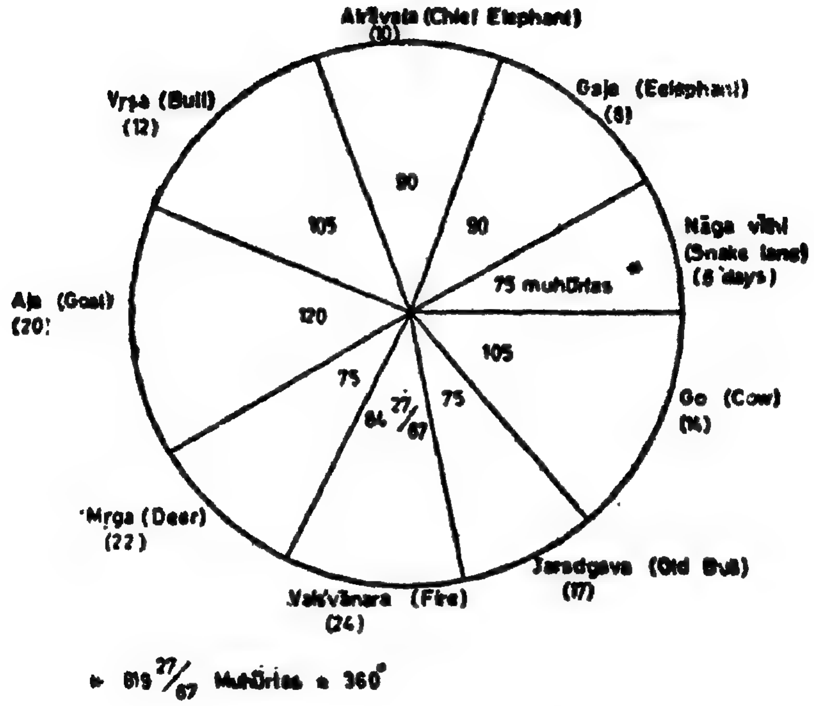


Fig. No. 7.1.—1 *Vithis (lanes) of venus, their zodiacal stretches in muhurtas of arc (1 muhūrta of arc denotes angular distance traversed by moon in one muhūrta or 48 minutes) and numbers of days venus remains in heliacal inferior combustion in them respectively.*

TABLE 7.1-4

VĪTHIS, THEIR ZODIACAL INTERCEPTS AND THEIR NUMBERS OF DAYS

Sr. No.	Vithi (lane)	Zodiacal intercepts (=ZS) in muhūrtas	Duration of inferior combustion in number of days D_n	$\frac{1}{D_n}$
1.	nāga (snake)	75	6	.166
2.	gaja (elephant)	90	8	.125
3.	airāvata (chief elephant)	90	10	.100
4.	vṛṣa (bull)	105	12	.083
5.	aja (goat)	120	20	.050
6.	mṛga (deer)	75	22	.046
7.	vaiśvānara (fire)	$84\frac{27}{67}$	24	2.04
8.	jaradgava (old bull)	75	17	.059
9.	go (cow)	105	14	.071

Thus vīthis (lanes) can be represented along the zodiacal circumference as shown in figure No. (7.1-1).

Now arc of combustion (angular stretch with respect to sun during which the planet remains heliacally invisible) of venus remains almost contant (see table 7.1.1), excluding rare cases when goecentric latitude of venus becomes very high for places at very high latitudes (see § 7.1). Thus mean velocity V_n of venus in nth vīthi during heliacal combustion can be defined as follows :

$$\int_0^{D_n} V dt = K$$

$$= V_n D_n \text{ (say)} \quad \ldots\ldots\ldots\ldots(7.1\text{-}1)$$

where K = constant (total length of arc of combustion)

In the integrand, V = Instantaneous relative geocentric velocity of venus which is a complicated function[8] of position of perigee of venus.

D_n = Duration (time counted in number of days) of heliacal combustion of venus in nth vīthi.

n = Serial number of vīthis arranged in natural order of nakṣatras associated with them such that n = 1 represents nāga vīthi and so on (see table 7.1-4)

Now from eq. No. (7.1-1), we have

$$V_1D_1 = V_2D_2 = \ldots\ldots\ldots = V_9D_9 = K \quad \ldots\ldots\ldots\ldots\ldots\ldots (7.1\text{-}2)$$

$$\therefore \quad V_1 : V_2 : \ldots\ldots\ldots V_9 : : \frac{1}{D_1} : \frac{1}{D_2} \ldots\ldots\ldots\ldots : \frac{1}{D_9}$$

$\therefore$ Mean velocity V_n of venus in different vithis (lanes) can be graphed by plotting $\frac{1}{D_n}$ against their respective zodiacal intercepts (see table 7.1-4) as shown in fig. No. (7.1-2).

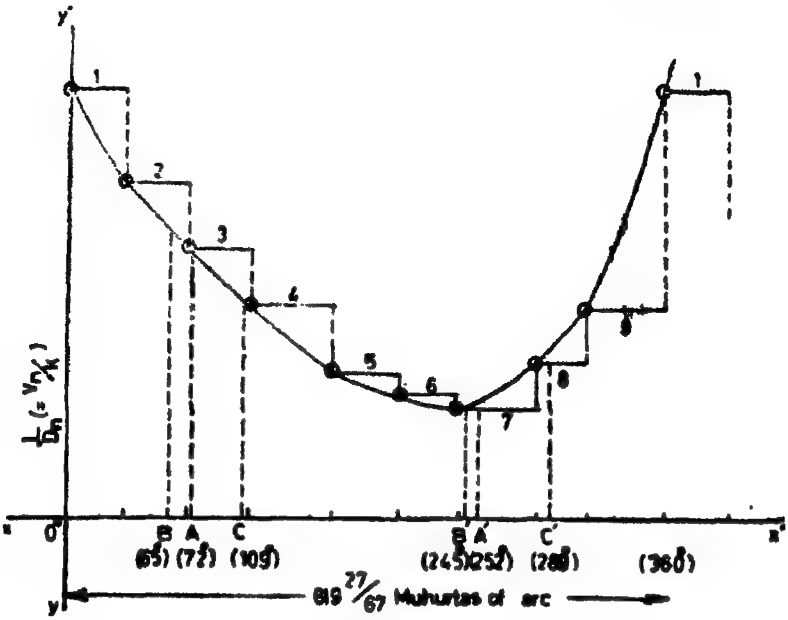
Besides, from eq. No. (7.1-1), we have

$$V_n = \frac{\int_O^{D_n} V dt}{D_n}$$

Now in vaiśvānara vīthi (n = 7), D_n is maximum (see table) 7.1-4)

$$V_7 = \frac{\int_O^{D_7} V dt}{D_7} = \text{minimum value (see table 7.1-4)}$$

Thus mean velocity of venus is minimum in Vaiśvānara vīthi (fire lane). This result stands true also for actual physical situation as shown below :



Names of Vīthis : 1. Nāga (Snake), 2. Gaja (Elephant), 3. Airāvata (Chief Elephant), 4. Vṛṣa (Bull), 5. Aja (Goat), 6 Mṛga (Deer), 7. Vaiśvānara (Fire) 8. Jaradgava (Old Bull) 9. Go (Cow).

Sidereal longitudes (assuming longitude of spica as 180°) in about 3rd century B.C.

Sun : Apogee = A, perigee = A′

Venus : Ascending node = B, Descending node = B′, Perihelion = C, Aphelion = C′

N.B. Sidereal longitudes in about 1975 A.D.[10] (and approximate velocities)

Sun : Apogee = 79° (+12″ per year)

Venus : Ascending node = 53° (—30′ per 95 years)
Perhelion=108° (—0′.01 per 19 years)

Fig. No. 7.1—2. *Graphic representation of mean velocity $V_n = (K/D_n)$ of venus during heliacal inferior combustion in different vīthis (lanes) among the lunar mansions under assumption of constant kālāṁśa (arc of visibility).*

We know that instantaneous relative geocentric velocity of venus,

$V = V_v - V_s$ ....(7.1-3)

where V_v = Heliocentric velocity of venus during geocentric retorgression

V_s = Apparent velocity of sun

Now as it is evident from fig. No (7.1-2) that perigee (point of apparent maximum geocentric velocity) A′ of sun lies in vaiśvānara vīthi i.e. V_s in vaiśvānara vīthi lies in the neighbourhood of its maximum value; and aphelion (point of minimum heliocentric velocity) C′ of venus lies very near to that i.e. V_v in vaiśvānara vithi lies in the neighbourhood of its minimum value. Thus in vaiśvānara vīthi the various values of V $(=V_v - V_s)$ would be smaller than its corresponding values in similar situations of venus in any other vīthi.

Consequently mean velocity V_n of venus will also be minimum in vaiśvānara vīthi (for n=7).

Likewise a similar treatment would hold good for other vīthis (lanes) of venus. Thus it may be contemplated that numbers of days D_n associated with various vīthis represent lengths of time for which venus remains heliacally set in their respective different parts of lunar zodiac. In the absence of an accurate knowledge of motion of venus, Jainas had developed empirical notion of mean velocity of venus in heliacal combustion in a particular vīthi (lane) among the lunar mansions. Such relative mean velocities of venus were estimated in a qualitative zigzag manner comparing them with some conventionally known velocities like those of snake, elephant etc. As there was no notion of sinosoidal functinos, such discrete step velocities were likely to be apprehended

(d) *DIRECTIONS OF VITHIS*

As regards direction of vithis, VS. 7.1-2 states : (Quotation No. 7.1-5).

i.e. "Go vīthi (cow lane) is situated at the middle line vṛṣabha (bull), gaja (elephant), airāvata (chief elephanet) and ; nāga (snake) vīthis (lanes) occur in the north and jaradgava

(old bull) mṛga (deer), aja (goat) and dahana (fire) vīthis (lanes) occur in the south."[3]

Besides, according to BTS.9.1, all the nine vīthis have been divided into three groups of three vīthis each, viz.[4] North vīthis : nāga (snake), gaja (elephant) and airāvata (chief elephant), Middle vīthis : vṛṣa (bull), go (cow) and jaradgava (old bull), South vīthis : mṛga (deer), aja (goat) and dahana (fire).

Each group is further divided into three groups of a single vīthi each,[5] e.g.

North vīthi : nāga (snake)
Middle vīthi : gaja (elephant)
South vīthi : airāvata (chief elephant)

Using table (7.1-2), relative directions of vīthis (lanes) may be shown in table (7.1-5).

TABLE 7.1-5

RELATIVE DIRECTIONS OF VĪTHIS OF VENUS

Sr. No.	Name of vīthi (lane)	Number of days associated with the vīthi	Relative directions*		
I	II	III	IV	V	VI
1.	nāga (snake)	6	N		
2.	gaja (elephant)	8	M	N	
3.	airāvata (chief elephant)	10	S		N
4.	vṛṣabha (bull)	12	N		
5.	go (cow)	14	M	M	M
6.	jaradgava (old bull)	17	S		
7.	aja (goat)	20	N		
8.	mṛga (deer)	22	M	S	S
9.	vaiśvānara (fire)	24	S		

*N.B. N=North, M=Middle, S=South

Now it is evident from table (7.1-5) that middle vīthi (lane) is associated with number of days lesser (or greater) than number of

days associated with northern (or southern) vīthi (see column IV). All the nine vīthis have verisimilarly been divided into three groups of three vīthis each (see column V). Likewise Go vīthi (cow lane) happens to be the middle one (see column VI).

It may be recalled that number of days for which venus remains heliacally set for a particular latitude of observer mainly depends upon geocentric latitude of venus. So go vīthi (cow lane) alludes to correspond to mean position (almost geocentric zero latitude) of venus. According to BBS, go vīthi (cow lane) is associated with Pūrvābhādrapada (α Pegasi), Uttarābhādrapada (γ Pegasi) and Revatī (ζ Piscium) nakṣatras (asterisms); whereas Aśvinī (β Arietis) was also added to the list by Varāhamihira et al. (see table 7.1-3). So go vīthi (cow lane) seems to have been used to occur near Spring equinox in those times. But according to Kaśyapa and Devala, go vīthi (cow lane) used to occur near Autumnal equinox because it is associated, according to them, with Hasta (δ Corvi), Citrā (α Virginis) and Svāti (α Bootis) nakṣatras (asterisms).

This also suggests that number of days associated with different vīthis, according to Kaśyapa and Devala, must also differ from those as given according to BBS. Kaśyapa and Devala had rearranged the pattern of allocation of nakṣatras (asterisms) kept in their natural order among the vīthis (lanes) kept in the prevailing sequence (decreasing or increasing) of numbers of days associated with them. Thus they committed a mistake by assuming parallelism between directions of vīthis and their regular placement along lunar zodiac. Such a parallelism does not hold good for individual vīthis due to several factors influencing duration of heliacal combustion of venus (see § 7.1); however in a broader sense, vīthis occurring north (or south) of go vīthi (cow lane) are associated with nakṣatras (asterisms) falling almost in northern (or southern) hemisphere (see table 7.1-3).

Now it may be recalled that relative directions of vīthis (lanes) of venus depend upon their respective numbers of days. Since duration of combustion of venus mainly depends upon its geocentric latitude (see § 7.1), so it may be envisaged that Jainas might have had a notion of geocentric latitude of venus implied in

relative directions of vīthis. Such a notion is rather supported by the fact that they had a notion of celestial latitude implied in concept of height above samatala bhūmi ('earth having plane surface' denoting a circular area with centre at the projection of pole of ecliptic) (see § 3.3).

(e) *GENERAL REMARKS*

It may be mentioned here that both in Maxican and Mayan manuscripts the periodic time of venus is indicated by means of the tonalamatl symbols and the dates of the month[8] respectively. Leaves 46-50 of the Mayan manuscripts in Dresden, exhibit five such revolutions of 584 days each which are severally divided into stages of 90, 250, 8 and 236 days.[13] But Jainian account of vīthis (lanes) of venus is unique in its features. May be that parallel studies were also in progress in both Maxican and Mayan civilizations.

Besides, the procedure text (Astronomical Cuneiform Text No. 812)[14] also describes intervals of invisibility of venus in inferior combustion and assigns[15]

15 days to Cancer and Leo

4½ days to Sagittarius

1 day to Capricorn and Aquarius

2 days to Pisces

According to Neugebauer,[16] the remaining data are lost and all dates of this type are subject to arbitrary interpretations, whether ½ day is included or excluded, because intervals of invisibility of venus in inferior combustion (evening setting and morning rising) by definition cannot amount to integer days. It is however worthy of note that these fragmentary data seem to have no similarities with the Jainian concept of vīthis (lanes), respective nakṣatras (and not ecliptic signs) associated with them, their respective numbers of days for which venus remains heliacally invisible. However a detailed discussion of these fragmentary data is out of scope of this exposition.

However such kinematical notions about the motion of venus did play an important role in the development of astronomy in

post-Jaina early Siddhāntic period in the history of ancient Indian astronomy. The BBS system of vīthis (lanes) of venus continued to be in vogue down to the period of VS wherein the concept of directions of vīthis (lanes) has been first elucidated. The synodic period of venus might have also been known as it is simply the periodic time between any two consecutive heliacal inferior (or superior) combustions of venus. All these gradual progresses in planetary kinematical studies extant in Jaina canonical and allied works are the studies parallel to those of old planetary ephemerides of menomides and seleucid period. Such kinematical studies of venus have left an everlasting effect on social activities of the Hindus who still observe heliocentric rising and setting of venus in their liturgical performances.

CHAPTER VIII

NOTES ON SOME MISCELLANEOUS TEXTS

This chapter comprises of notes on some miscellaneous texts.

8.1. *CYCLES OF ECLIPSES IN JAINA ASTRONOMY*

(a) *INTRODUCTION*

According to Siddhāntic astronomy and modern Indian astrology, moon's ascending node is symbolically represented as rāhu (dragon's head). However Jainas had conceived two kinds of rāhu. SP. 20·13 states : (Quotation No. 8.1-1).

"(Rāhu) is of two kinds—'dhruva rāhu' and 'parva rāhu.' Dharuva rāhu covers moon (with darkness) at the rate of 1/15th part of the lunar disc per lunar day in the lunar dark half, *i.e,* first 1/15th part on first lunar day . . . fifteenth, 1/15th part on fifteenth lunar day. At the ending moments (of amāvasyā or new-moon day), the moon is totally covered (with darkness).

In the lunar bright half (dhruva) rāhu withdraws darkness from moon at the same rate *i.e.* 1/15th part (of the lunar disc per lunar day) from first lunar day upto fifteenth lunar day till moon is perfectly uncovered. On other times, moon is partially covered or uncovered.

Parva rāhu covers (moon and sun) at least (once) in six months and excellently moon (once) in forty-two months and sun (once) in forty-eight year."

This is explicitly stated in BS. 3.12.6.1 also.

Thus it appears plausible that dhruva rāhu as implied in Jaina texts, seems to denote the shadow which covers moon with darkness in fifteen lunar days of the lunar disc per lunar day and removes the darkness at the same rate in the lunar bright half. Likewise parva rāhu as implied in Jaina texts, denotes the shadow which covers moon and sun with darkness during their eclipses respectively. A nine-fold nomenclature of parva rāhu is stated in SP. 20.6 as : (Quotation No. 8.1-2).

"There are nine names of (parva) rāhu, viz.

(1) Siṅghāḍae,	(4) Khetae,	(7) Maccha,
(2) Jaḍilae,	(5) Ḍhaḍḍhare,	(8) Kacchapa,
(3) Kharae,	(6) Magara,	(9) Kṛṣṇasarpa".

Besides, it is worthy of note that an account of a nine-fold classification of eclipses is also found in Jaina canon. In this context, SP. 20.9-10 states : (Quotation No. 8.1-3)

"(1) When (parva) rāhu coming, going (and) moving on its path, covering the light of moon or sun from the eastern direction, goes towards the western direction; moon or sun appears in the east and rāhu in the west.

When (parva) rāhu) . . . covering (the light of moon or sun) from the western direction goes towards the eastern direction.

(2) When (parva) rāhu . . . covering the light from the southern direction goes towards the northern direction.

(3) When (parva) rāhu . . . covering the light from the south-eastern direction goes towards the north western direction.

(4) When (parva) rāhu . . . covering the light from the south-western direction moves towards the northeastern direction; (rāhu) covering (the light) from the north-western direction goes towards the south-eastern direction; . . . (rāhu) . . . covering (the light) from the north-western direction goes towards the south-western direction.

(5) When (parva) rāhu . . . remains stationary after covering (the light of) moon or sun, people say that rāhu has swallowed moon and (or) sun.

(6) When rāhu...moves by the side of moon or sun, people say that rāhu has pierced through the side of moon or sun.

(7) When rāhu...returns after covering moon or sun, people say that rāhu has left moon or sun.

(8) When rāhu ..covers some of the central portion of moon or sun, people say that rāhu has pierced the centre of moon or sun.

(9) When rāhu...perfectly covers moon or sun, people say that rāhu has fully swallowed moon or sun."

This shows that Jainas had studied that an eclipse begins from any of the directions viz. east, south, south-east, south-west and north-west and it also begins to disappear from the same direction (1-4). Besides they had made observations regarding steadiness of the maximum eclipse (5) ; narrow escape from the occurrence of an eclipse (6) ; reappearance of the lunar or the solar disc after the eclipse is over (7) ; annular eclipse (8) ; and total eclipse (9). It may evidently be contemplated that exponents of Jaina school of astronomy had carefully studied several features of eclipses. It may be envisaged that nine-fold classifications of the eclipses and the parallel nine-fold nomenclature of parva-rāhu suggest that parva rāhu as implied in Jaina texts denotes verisimilarly the shadow of lunar nodes closely linked with the phenomenon of eclipse formation. However etymological analysis of name-variants (nine-fold nomenclature) of parva rāhu is in progress.

It is however worth mentioning that not only Jainas had developed cosmic notions like that of 'parva rāhu' as implied in Jaina texts but similar view points were prevalent among some other ancient peoples also. For instance, at the time of a solar eclipse, Chinese thought that sun was being swallowed by a huge dragon and the whole population joined in making as much noise as possible to scare it away.[28] However Jainas had tended to probe into the nature of such a dragon in their astronomical pursuit for the interpretation of the phenomenon of eclipse formation.

Now it may be recalled that an eclipse occurs when earth falls in a straight line with the two luminaries, solar eclipse on a new

moon day and lunal eclipse on a full moon day. Due to inclination of the moon's orbital plane to the plane of ecliptic, the number of eclipses is restricted. Sun's angular distance from a node if an eclipse is just possible, is called ecliptic limit. The ecliptic limit is a variable quantity, its maximum value is called superior ecliptic limit and least value inferior ecliptic limit. Superior and inferior ecliptic limits are 18°.4 and 15°.5 (solar eclipse) and 12°.1 and 9°.5 (lunar eclipse) respectivvely.[1]

In many ancient countries like China and Babylon, records of occurrence of eclipses had been kept. Ptolemy of Alexandria (ca. 150 A.D.) had before him a record of eclipses kept at the Babylonian archives dating from 747 B.C. and he gave dates of occurrence, time and features of the eclipses, whether they were partial or total. Chaldean astronomers tried to discover the laws of periodicity of eclipses which ultimately about 400 B.C., resulted in the discovery of the Saros cycle of eighteen years and ten or eleven days.[2] Besides, it is also believed that Metonic cycle of nineteen years of 365¼ days each was discovered first by Meton, an Athenian astronomer, about 433 B.C.[3] One view is also that the Chinese might have discovered the metonic cycle before the Greeks.[4] In Vedic India also, there existed an eclipse cycle of 20,000 days (675 lunations or fifty-six lunar years and three months). The Vedic poets distinguished the recurrence of eclipses into three different colours[39] such as black, red and white in the course of three cycles and the reappearance of an eclipse in its original colour in the fourth cycle ; hence if we divide fifty-six years and three months by three, we get eighteen lunar years and nine months for one cycle of eclipses.[5] In Jaina texts, five colours have been ascribed to parva rāhu. In this context, SP. 20.6 states : (Quotation No. 8, 1-4).

> "There are five colours of (parva) rāhu, viz. Kṛṣṇa (black), Nīle (blue), Lohita (red), Pīta (yellow), and Śukla (white)."

In the light of foregoing exposition of parva rāhu as implied in Jaina texts, it may however be contemplated that colours of (parva) rāhu imply the notion of colours of eclipses. Thus accord-

ing to Jaina tradition, the eclipses recurred into five different colours. This hints upon an advancement over Vedic theory of recurrence of eclipses into three different colours.

(b) FREQUENCY OF ECLIPSES

The frequency of eclipses in a year is minimum two and both of them are solar eclipses.[6] The time interval between them is almost equal to half the length of an eclipses year because during this period the sun changes its position from the neighbourhood of either node of the lunar orbit to the neighbourhood of the other node and moon also falls again in conjunction with sun. It can easily be seen that

$\because$ an eclipse year[7] = 346.62 days, and
lunar synodic month[7] = 29.53 days

$\therefore$ half the length of
an eclipse year = 173.31 days, and
6 lunar synodic
"months" = 177.18 days

$\therefore$ Half the length of an eclipse year$\sim$6 lunar synodic months.

This indicates that, with due account of ecliptic limits at least, one (solar) eclipse must occur within a period of about six months.[8] The fact is also practically verified from any list of esclipses over a century or so.[9] If the frequency of the eclipses is more than two in a year, the relative time interval between them will however be decreased further. Therefore Jaina notion that parva rāhu covers moon and (or) sun at least once in six months is justifiable.

(c) PERIODICITY OF LUNAR ECLIPSES

According to Jaina texts (see Quot. 8.1-1), parva rāhu covers moon excellently (once) in forty-two months. The suggests a forty two-month cycle of luuar eclipses. Now let us probe into the rationale of this theory and see if this forty-two-month cycle of lunar eclipses can also be theoretically generated.

A lunar eclipse is visible in the same degree on every part of earth's sphere turned away from sun or speaking broadly, on any

meridian between the hours of sunset and sunrise.[14] As we have expounded earlier that eclipses were known by their different colours corresponding to those of (parva) rāhu ; so theoretically a lunar eclipse of any particular colour would repeat in the same colour after a period P such that

1. P contains the number of days integral multiple of the number of days in half an eclipse year because sun's angular distance from lunar nodes, the same node or the other as the integer is even or odd as the case may be, falls again within ecliptic limits,

2. P contains N lunations (where N is a positive integral number) because moon again must be full at that time.

Taking about 173 days as the length of half an eclipse year and 29.5 days the lunation, it may easily be seen that P is equivalent to N lunations if

$$P = 29.5\,N = 173\,x$$

$$\text{or } N = \frac{173x}{29.5} \quad (8.1\text{—}1)$$

where 'x' is a positive integer.

Let $\{N\}$ and $\{x\}$ denote two sets of possitive integers such that.

$$\{N\} = \{N_1, N_2, N_3 \ldots\ldots\ldots \quad N_n\} \text{ and}$$

$$\{x\} = \{x_1, x_2, x_3 \ldots\ldots\ldots \quad x_n\}$$

$\{x\}$ cannot be mapped to $\{N\}$ because

$N \neq f(x)$ for all x, where $x \in \{x\}$

Eq. No. (8.1-1) may also be written as

$$N = \frac{346\,x}{59} \qquad (8.1\text{-}2)$$

Parametric solution of this equation is given as

$$\left.\begin{aligned} N &= 346\,c + 346 \\ x &= 59\,c + 59 \end{aligned}\right\} \qquad (8.1\text{-}3)$$

where c is a parameter.

Now, for $N>O$, $346\,c + 346>O$, or $c>-1$,

and for $x>O$, $59\,c + 59>O$, ar $c>-1$,

But for $c = O$,

$x = 59$, $N = 346$, is one of the solutions.

But to arrive at a better solution, we are to find the value of c defined as $-1 < c < O$, such that

$N = f(x), [x ; x \in \{x\}]$

Now let us solve the parametric eq. No. (8.1-3)

$\because$ N and x are integers ; and an arbitrarily chosen number 5 is also an integer.

$\therefore$ $(N - 5x)$ is also an integer.

Thus from eq. No. (8.1-3), we have

$51c + 51 = N - 5x = N'$, where N' is an integer.

$$\text{or } c = \frac{N'-51}{51} \qquad (8.1\text{-}4)$$

Now from eq. No. (8.1-3), we have

$x = -59k+59$ where $k = -c$

Evidently for x to be minimum, k should be maximum possible.

From eq. No. (8.1-4) we have

$$k = \frac{51\text{-}N'}{51} \qquad (8.1\text{-}4)$$

Evidently for k to be maximum, N' should be minimum possible.
Now if $N' = O$, $c = -1$

But $c \neq -1$ ($\because$ c is defined as $-1 < c < O$

$\therefore$ $N' \neq O$

Now putting value of c from eq No. (8.1-4) in eq, No. (8.1-3), we get

$$x = 59\left(\frac{N'-51}{51}\right)+59$$

$$= \frac{59}{51}N'$$

$$= \left(1+\frac{8}{51}\right)N'$$

$$= N' + \frac{8N'}{51} \qquad (8.1\text{-}6)$$

For x to be possible least positive integer,

$$\frac{8N'}{51} = X' \qquad (8.1\text{-}6)$$

where X' = least positive integer.

$\therefore$ Putting $X' = 1$, we get

$$N' = \frac{51}{8} = 6 + \frac{1}{2+}\;\frac{1}{1+}\;\frac{1}{2}$$

$\approx$ 6 (first approximation)

$\therefore$ from eq. No. (8.1-6), we get the possible least positive integer

$$x = 7$$

Thus putting value of x in eq. No. (8.1-2), we get

$$N = \frac{346 \times 7}{59} = 41.05 = 41 \text{ lunations approx.}$$

Now $\because$ 41 lunations $= 41 \times 29.53 = 1210.73$ days, and

$$42 \text{ eclipse months} = \frac{346.62 \times 42}{12} = 1213.17$$

Obviously, 42 eclipse months $\approx$ 41 lunations.

The lunar eclipse in its original colour recurs after forty-one lunations or forty-two eclipse montns. Thus the Jainian notion that parva rāhu excellently covers moon (once) in forty-two (eclipse) months is meaningful.

(d) PERIODICITY OF SOLAR ECLIPSES

According to Jaina texts (see quot. No. 8.1-1), parva rāhu coverse sun excellently (once) in forty-eight years. This suggests

forty-aight-year cycle of solar eclipses can be generated theore tically as follows:

The visibility of a solar eclipse differs from place to place on earth. So the cycle of solar eclipses needs be referred to a particular locality only. The solar eclipse at any particular locality can recur in its original colour after a period P such that

1. P contains an integral number of sidereal revolutions of sun because eclipse may again be visible in that particular locality.
2. P contains an integral number of lunations because moon must also again be in conjunction with sun.

However, as implicit in the theory of the-then-in use Jaina fixed quinquennial cycle[9], conjunction between sun and moon at a particular location among the stars recurs after a period of five years (see 6.8). Thus the cycle of solar eclipse repeats after a period of P such that

$$P = 5\,x \text{ years} \tag{8.1-1}$$

where x is a positive integer.

3. Sun's distance from either node of moon's orbit should again fall within ecliptic limits.

Since the sidereal period of rāhu is 18.60 years,[10] rāhu (moon's ascending node) and ketu (moon's descending node) interchange their positions after 9.30 years. So the period of repitition of the solar eclipses should also be an integral multiple of 9.30 years. But it may be noted that the angular distance between inferior ecliptic limits (solar ecliptic) is about 30° and it is traversed by rāhu (or ketu) in $\frac{18.60}{360} \times 30 = 1.55$ years. So if an eclipse occurred with rāhu having lesser longitude than that of sun, a similar eclipse can repeat even if rāhu is placed on the other side of sun with the same difference of longitude; this happens to be at least 1.55 years earlier and vice versa also.

$$\therefore P = 9.30y \mp 1.55 \tag{8.1-9}$$

where y is a positive integer.

Now let us solve eq. No. (8.1-8) and eq. No. (8.1-9). From these equations, evidently we have

$$P = 5x = 9.30y \mp 1.55$$

or $x = 1.86y \mp .31$

$$\text{or } x = \frac{186y \mp 31}{100} \qquad (8.1\text{-}10)$$

Now $\because$ 186 and 100 have a common factor,

$\therefore$ Eq. No. (8.1-10) cannot have an exact integral solution.

This can however be written as

$$x = \frac{93y \mp 15.5}{50} \qquad (8.1\text{-}11)$$

For the least approximate integral solution of eq. No. (8.1-11), we apply Kuṭṭaka (Pulveriser) and the Valli method[18], i.e. theory of indeterminate equations of first degree.

Rūpa-Kuṭṭana or the auxiliary Kequation is

$$x = \frac{93y - 1}{50},$$

odd Valli (1 13
(1 7
(6 0
(1
(0

$\therefore$ Auxiliary solution is

$y = 7$
$x = 13$

For Kṣepa (additive) $= \mp 15.5$
$y = \mp 8.5$
and $x = \mp 15.5$

$\therefore$ Parametric solution of eq. No. (8.1-11) with parameter c is given as

$$\left.\begin{array}{l} y = 50c \pm 8.5 \\ x = 93c \pm 15.5 \end{array}\right\} \qquad (8.1\text{-}12)$$

for $y > 0$, $c > \mp \frac{8.5}{50}$ or $c > \mp \frac{1}{6}$

$$\text{for } x > 0,\ c > \mp \frac{15.5}{93} \text{ or } c > \mp \frac{1}{6} \qquad (8.1\text{-}13)$$

Besides, from eq. No. (8.1-12), we have

$$\left.\begin{aligned} x + y &= 143c \pm 24 \\ x - y &= 43c \pm 7 \end{aligned}\right\} \qquad (8.1\text{-}14)$$

$x + y$ and $x - y$ are integers, for x and y are integers.

Now $\because$ $x + y$, $x - y$, 24 and 7 are integers,

$\therefore$ 143c and 43c are also integers.

Let $143c = t$
$43c = m$

where t am m are arbitrarily chosen integers.

$$\therefore\ c = \frac{t}{143} = \frac{m}{43} \qquad (8.1\text{-}15)$$

Now $\frac{143}{43} = 3 + \frac{1}{3+}\ \frac{1}{14}$

The first approximation i.e. $\frac{143}{43} \simeq 3$, is too rough, and the third approximation i.e.

$\frac{143}{43} = \frac{143}{43}$ is not required.

We take the second approximation i.e.

$$\frac{143}{43} \simeq \frac{10}{3}$$

$\therefore$ Eq. No. (8.1-15) can be written approximately as

$$c = \frac{t}{14 \times 10} = \frac{m}{14 \times 3}$$

$$\text{or } 14c = \frac{t}{10} = \frac{m}{3} = k \qquad (8.1\text{-}16)$$

where k is an integer such that t ($= 10$ k) and m ($= 3$ k) are also integers.

To get possible least value of c, let k be the least integer, i.e.

$k = +1$

Now two cases arise

1. Either $14c = k = +1$

or $c = \frac{1}{14} < \frac{1}{6}$

But $c > \frac{1}{6}$ (see eq. No. 8.1-13)

$c \neq -\frac{1}{14}$

or $k \neq 1$

2. Or $14c = k = -1$

or $c = -\frac{1}{14} > -\frac{1}{6}$ (see eq. No. 8.1-13)

Therefore t and m are integers arbitrarily chosen such that

$c = \frac{1}{14}$

Putting value of c in eq. No. (8.1-12), we have

$y = -\frac{50}{14} \pm 8.5$

$= +5$ or -12 approximately

$\because$ y is, by definition, a positive integer,

$\therefore y \neq -12$

$\therefore y = +5$

Putting this value of y in eq. No. (8.1-9), we have

$P = 9.30 \times 5 \mp 1.55$

$= 45$ or 48 years approx.

Now two cases arise.

1. Either $P = 48$ years

from eq. No. (8.1-8), we have

$$5x = 48$$

or $x = \frac{48}{5} \neq$ an integer ($\because$ x is, by definition, a positive integer)

$\therefore P \neq 48$ years

2. or $P = 45$ years

$\therefore$ from eq. No (8.1-8), we have

$$5x = 45$$

or $x = 9$ (an integer)

$\therefore P = 45$ years approx.

$$= \frac{45 \times 366}{346} = 47.6 \text{ eclipse year}$$

$$= 48 \text{ eclipse years approx.}$$

$\therefore$ 45 years $\approx$ 48 eclipse years.

Thus the Jaina notion that parva rāhu excellently covers sun (once) in forty-eight (eclipse) years is meaningful and justifiable.

Besides, be it noted that $y = 5$ i.e. the number of half cycles of either node of moon's orbit during one cycle of solar eclipses is odd. So at the beginning of next 48-(eclipse) year-cycle of solar eclipses the nodes intercharge their positions. Thus parva rāhu (that causes eclipses) denotes both rāhu (moon's ascending node) and ketu (moon's descending node). Ergo it is quite convincing that by identifying the five colours of parva rāhu (eclipse shadow as implied in Jaina canonical texts) Jainas might have conceived an empirical notion for the motion of parva rāhu of a particular co'our passing through the same zodiacal intercept among the stars once during one eclipse cycle of sun. It is, however, contemplable that they were not well-acquainted with an accurate knowledge of true motion of lunar nodes.

(c) *CONCLUSION*

The phenomenon of eclipse formation was distinctly known to Jainas. They had known the frequency of eclipses in a year and also the periodicity of lunar and solar eclipses respectively. If we combine the two cycles of forty-eight (eclipses) months or $3\frac{1}{2}$ (eclipse) years and forty-eight (eclipse) years, we have a bigger luni-solar cycle of 336 (eclipse) years. It cannot be affirmed with certainty if Jainas had obtained the luni-solar eclipse cycle of 336 (eclipse) years, but such probability is, of course, worth-contemplating because the component cycles were undoubtedly known to them. It is however worth mentioning here that in original text, the absence of any names of month and year implied in Jaina cycles of lunar and solar eclipses suggests that Jainas might have considered them different from lunar month and lunar year etc. respectively. Did Jainas mean that the month and the year used in context of motion of rāhu causing eclipses, denoted a rāhu month (eclipse month, in modern terms) and a rāhu year (eclipse year, in modern terms) respectively? In the light of our expositions, it seems so.

These eclipse cycles have not been unearthed elsewhere so far. These cycles are peculiar to Jaina School of astronomy and they exhibit a unique advancement over the Vedic theory of periodicity of eclipses. It appears that Jainas had developed these cycles through naked eye observation of colours of eclipses. However it cannot be ascertained whether or not Jainas had known the theoritical rationale of their notion of eclipse cycles. But because they had established their cycles of eclipses, so naturally it may be inferred that Jainas could predict an eclipse in advance. Babylonians could also predict eclipses as long ago as the sixth century B.C.[11] The contemporary earliest Lonian philosopher Thales of Milletus born about the year B.C. 640, was able to predict a solar ecipse or at least the year in which it happened (probably B.C. 585'; but it had also become a fashion to consider Thales as the author of many scientific and philosophical truths which in reality were not known till long after his time.[12]

However, it must be mentioned here that

336 eclipse year = 116464.22 days) (8.4-17)
and 3944 lunations = 116468.69 days)

There is a difference of 4.87days.

Similarly, 48 eclipse year = 16637.75 days) (8.4-18)
and 563 lunations = 16625.73 days)

There is a difference of 12.03 days i.e. a little less than half the lu a-tion. On the other hand, we know that according to the chaldean Saros,

19 eclipse year = 6585.8 days)
and 223 lunations = 6585.3 days) (8.5-19)

19 years of $365\frac{1}{4}$ days each = 6939.75 days) (8.5-20)
and 235 lunations = 6939.69 days)

Comparing relations (8.4-17) and (8.4-18) with relations (8.4-19) and (8.4-20), it may easily be seen by inspection that the former equations have no relation with the latter equations. It shows that the Jaina cycles of eclipses are independent of any influences of the Chaldnea Saros and the Metonic cycle. Compared Chaldean Saros, the Jaina cycles of eclipses do not corroborate any sound knowledge of true motion of lunar nodes. Thus the merit of Jaina cycles of eclipses lies only in the fact that they were devised through naked eye observation of colours of eclipses in the absence of an accurate knowledge of the true motion of lunar nodes. Incidently it may be remarked that t' e Saros cycles cannot be carried indefinitely either forward or backward due to the fact that the Saros cycle is not an exact multiple of either a lunation or an eclipse year.[35] In this respect Jainian approach towards finding the eclipse-year cycles of eclipses seems to be more empirical. However, Jainian original approach is worth eulogising.

8.2 NOTION OF CELESTIAL LATITUDE THE CONCEPT OF DIRECTIONS OF LUNAR CONJUNCTIONS WITH NAKṢATRAS (ASTERISMS)

Antiquity of the phenomenon of 'pramarda yoga' (literally, occultation) or conjunction of moon with nakṣatras is traced back to the Vedic period [18] The modern concept of lunar occultation (the disappearance of asterism from view behind the moon)[37] should not be confused in the present context. There are several kinds of 'pramarda yogas' or occultations (conjunctions of moon with

nakṣatras, meaning henceforth also) like kalāyuti (longitudes equal), bhedayuti (declinations equal) etc. Besides, on the second lunar day of the lunar dark half, the line of moon's cusp is directed towards the identifying star of the nakṣatra (asterism) which is occupied by moon also on the fifteenth lunar day (full moon day) of the lunar bright half of that month. The month is also called after the name of nakṣatra (asterism) occupied by moon on the full moon day. The nomenclature of the months is based on this theory in spite of the fact that the conjunction stars of many nakṣatras (asterisms) like those of Abhijit (α Lyrae) and Svāti (α Bootis) lie so distant from the region where moon passes among the stars. Probably Hindus preferred brighter stars rather than the fainter ones near the ecliptic to mark the lunar mansions. In the light of this discussion, a simple proble is rendered into some data regarding the directions of lunar pramarda yogas (occultations) or conjunctions with nakṣatras (asterisms). In this context JP.9.3 states : (Quotation No. 8.2-1)

> "Out of these twenty-eight nakṣatras (asterisms) there are six nakṣatras viz. Mṛgaśirṣa, Āṛdrā, Puṣya, Āśleṣā, Hasta (and) Mūla, which always occult (or conjoin with) moon from the southern directions. (These) are (situated) outer than the outermost (lunar) maṇḍala (diurnal circle).
>
> Out of them, there are twelve nakṣatras (asterisms) viz. Abhijit, Śravaṇa, Dhaniṣṭhā, Śatabhiṣā,, Pūrvābhādrapada Uttarābādrapada, Revatī, Aśvinī Bharaṇī, Pūrvāphālguṇī, Uttarāphālgunī (and) Svāti, which always occult moon from the northern direction.
>
> Out of them there are seven nakṣatras (asterisms) viz. Kṛttikā, Rohiṇī, Punarvasu, Maghā Citrā, Viśākha (and) Anurādhā, which always occult moon from the southern and the northern directions.
>
> Out of them there are two Aṣāḍhās which always occult moon from the southern direction. They are conjoined with the outermost lunar mandala (diurnal circle).
>
> Out of them, there is only one Jyeṣṭhā nakṣatra (asterism) which always occults moon."

This is explicitly stated in SP.10.11 also.

All the nakṣatras (asterisms) and their English equivalents along with their latitudes[13] are shown in table 8.2-1.

It is evidently seen by inspection from table (8.2-1) that the category 'A' (nakṣatras or asterisms which always occult moon from the southern direction) consists of nakṣatras, save Puṣya (δ Cancri), whose latitudes are greater than maximum southern latitude of moon. Category 'B' (nakṣatras or asterisms which always occult moon from the northern direction) consists of nakṣatras, save Śatabhiṣā (λ Aquarii) and Revati (ζ piscium), whose latitudes are greater than the maximum northern latitude of moon. Latitudes of nakṣatras (asterisms) of category 'C' (nakṣatras or asterisms which always occult moon from the southern and the northern directions) fall within the belt of lunar zodiac and they occult moon from both the southern and the northern directions depending upon the positions of lunar nodes. The two Āṣāḍhās i.e purvāṣāḍhā (ξ Sagittarii) and Uttarāṣāḍhā (σ Sagittarih) of categori 'D' (the two Aṣāḍhās which occult moon from the southern direction) have their latitudes very close to the maximum southern latitude of moon. Perhaps that is why they have been distinguished from those of category 'A'. Besides, the latitude of Uttarāṣāḍhā (σ Sagittarii) lies somewhat inside the belt of lunar zodiac but it has been associated with Pūrvaṣāḍhā (δ Sagittarii) probably because they gave more weight to the star-figure Aṣāḍhā as a whole composed of two parts viz. Pūrva (first) and Uttara (second) (see 6.7.b) just as two Phālgunīs (Pūrvāphālgunī or δ Leonis and Uttarāphālgunī or β Leonis) make one star-figure and they belong to one category and similarly two Bhādrapadas (Pūrvābhādrapada or α Pegasi and Uttarābhādrapada or γ Pegasi) also do so.

However, it appears from category 'C' (nakṣatras or asterisms which occult moon from the southern and the northern directions depending upon the position of lunar nodes) that it could not escape their attention that any nakṣatra (asterism) like that of category 'E' (the only Jyeṣṭhā or α Scorpii which always occults moon) cannot overlap moon for all the times. Moreover such a knowledge is also implied in the famous Vedic story of Rohinī Śakaṭa Bheda i.e. the moon piercing through the cart of Rohini (α Tauri) nakṣatra (asterism) after every 18½ years period.[14] Thus

it is contemplable that either the data may have been recorded when Jyeṣṭhā (α Scorpii) used to overlap the moon for a few months at a stretch as the phenomenon almost parsists over, or a different star figure of Jyeṣṭhā (α Scorpii) nakṣatra extending over the southern half of the belt of lunar zodiac might have been misconceived. Likewise, they might have had some different identifying stars of Puṣya (δ Cancri) Satabhiṣā (λ Aquarii) and Revatī (ξ Piscium nakṣatras (asterisms) or the positions of these three nakṣatras (asterisms) underwent some sort of later interpolation in their categorization vide table (8.2-1).

In the light of foregoing discussion, it may be concluded that Jainas had indentified the belt of lunar zodiac. An empirical notion of celestial latitude of moon is also Implied therein. However, the notion of latitude of moon implied in the concept of 'height' above 'samatala bhūmi' has already been dealt with (see 3.3).

8.3. *CHATRĀTICHATRA YOGA (LUNAR OCCULTATION WITH CITRA i.e. α VIRGINIS)*

According to Jaina canonical literature there are ten kinds of lunar yogas (weal and woe conjunctions,. Only the Chatrātichatra Yoga (=CY) of them is defined therein. This section renders a simple probe into the concept of CY. It is revealed that the CY was probably defined with respect to the cardinal points. Some light is also thrown upon Jainian trends towards the study of celstial phenomena.

As regards the classification of lunar yogas, SP.12.25 states as: (Quotation No. 8.1-3)

> "There are ten kinds of yogas (weal and woe conjunctions), viz.
>
> 1 Vṛṣabhānujāta,
> 2. Veṇukanūjāta,
> 3. Mañca,
> 4. Mañcātimañca,
> 5. Chatra,
> 3. Chatrātichatra,
> 4. Yuganaddha,
> 8. Ghanasammarda,
> 9. Prīnita
> 10. Maṇḍukapluta."

However, only the CY is defined. In this context, SP.12 26 states : (Quotation No. 8.3-2)

> "In Jambūdvīpa, draw east-west and north-south lines. Divide the maṇḍala (diurnal circle) into 124 parts. Leave twenty-seven parts in south-eastern quarter of the maṇḍala (diurnal circle) and divide the twenty-eighth part into twenty sub-parts. Leave eighteen sub-parts. Divide the nineteenth sub-part into three sub-sub-parts. The moon is associated with two sub-sub-parts at the time the CY is formed in the south eastern quarter of the maṇḍala (diurnal circle). Upper the moon, middle the nakṣatra (asterism) and lower the sun are (relatively situated at that time).
>
> Which nakṣatra (asterism) does the moon occult at that time ? (The moon occults) Citrā (α Virginis) at (its) ending moments."

These details of the CY (literally, to overlap like an umbrella) work out as follows :

(i) 1 lunar maṇḍala (diurnal circle) $= 124$ parts

1 part $= \dfrac{1}{124}$ lunar maṇḍala

1 sub-part $= \dfrac{1}{124} \times \dfrac{1}{20}$ lunar maṇḍala

1 sub-sub-part $= \dfrac{1}{124} \times \dfrac{1}{20} \times \dfrac{1}{3}$ lunar maṇḍala

$\therefore$ Zodiacal stretch of CY $=$ 2 sub-sub-parts

$= \dfrac{1}{3720}$ lunar maṇḍala (diurnal circle...... (8.3-1)

Now as we know that according to Jaina five-year fixed calendar (see table 6.9-1), we have

1768 lunar maṇḍalas (diurnal circles) = 67 lunar sidereal revolutions (nakṣatra months) of $819 \frac{27}{67}$ muhūrtas of arc each (see 2.3)

= 54900 muhūrtas of arc

$\therefore \frac{1}{3720}$ lunar maṇḍala (diurnal circle) $= \frac{915}{109616}$ muhūrta of arc

= .401 minute approx.

($\because$ 1 muhūrta = 48 minutes)

So the CY occurs for about ·40 minute only.

(ii) Besides, counting from the beginning of the lunar maṇḍala (diurnal circle), we have

Longitude of CY = 27 parts + 18 sub-parts

$= \frac{9}{40}$ lunar maṇḍala (diurnal circle)........ (8.3-2)

Besides, we know that the zodiacal circle was graduated in $819 \frac{27}{67}$ muhūrtas and its zero coincided with the beginning of Abhijit (α Lyrae) nakṣatra (see 2.3). Therefore moon traverses 54900 ($= 819\frac{27}{67} \times 67$) muhūrtas of arc (one muhūrta of arc equals the angular distance traversed by moon by mean motion in one muhūrta i.e forty-eight minutes) in sixty-seven lunar sidereal revolutions i.e. in a five year cycle which contains 1768 lunar maṇḍalas (diurnal circles).

$\therefore$ Velocitv of moon

among the stars, v_m $= \frac{54900}{1768}$ muhūrtas of arc/lunar maṇḍala (diurnal circle)

$\therefore$ Considering the absolute motion of moon, we have

Total geocentric angular distance traversed by moon in one lunar diurnal circle = Zodiacal circle + eastward motion of moon among the stars per lunar manḍala (diurn l circle)

$= 819\frac{27}{67} + \frac{54900}{1768}$ muhūrtas of arc

Apparent geocentirc angular length of a lunar maṇḍala (diurnal circle). $= \frac{54900}{67} \times \frac{1835}{1768}$ muhūrtas of arc

$\therefore$ Apparent angular

length of $\frac{9}{40}$ lunar maṇḍala (diurnal circle) $= 191\frac{83483}{236912}$ muhūrtas of arc

$= 84^\circ$ approx.... ....(1.3-3)

$\because 819\frac{27}{67}$ muhūrtas $= 360^\circ$

So the longitude of the ascending point of the zodiacal circle occurs at $191\frac{83483}{236912}$ muhūrtas of arc ahead of the ending moments of Citrā (α Virginis) or in other words, Uttarāṣāḍhā (σ Sagittarii) with $18\frac{153429}{266912}$ muhūrtas as its balance (see table 2.3-1) was ascending at the time of formation of CY. According to Jaina fixed calender,[15] winter solstice occured at the beginning of Abhijit (α Lyrae) or the final portion of Uttarāṣāḍhā (σ Sagittarii). Therefore it appears that CY was probably defined with

respect to the cardinal point Winter solstice which had receded $18\frac{153429}{266912}$ muhūrtas of arc back from the beginning of Abhijit (α Lyrae). This is of course a mere conjecture. However in the light of this discussion, it may be envisaged that the east-west line passes almost through the solstitial points and thus it exhibits, albeit inadequately, a notion of ecliptic and therefore the north-south line passes almost through the equinoctial points. Taking seventy-two years for 1° precession, we find that the event had taken place Y years after the Winter solstice coincided with the beginning of Abhijit (α Lyrae) such that

$$y = \frac{360}{819\frac{27}{67}} \times 18\frac{153429}{266912} \times 72 = 588 \text{ years approx}$$

$$(\because 819\frac{27}{67} \text{ muhūrtas of arc} = 360°)$$

Thus the event might have occurred in the early centuries of Christian era.

(iii) Now as we know that velocity of moon among the stras,

$$v_m = \frac{54900}{1768} \text{ muhūrtas of arc/lunar maṇḍala}$$

$\therefore$ The zodiacal stretch traversed by the moon in 9/40 lunar maṇḍala $= \frac{9}{40} \times v_m$

$$= 6\frac{6978}{7072} \text{ muhūrtas of arc} \ldots\ldots\ldots\ldots (8.3\text{-}4)$$

$\therefore$ Longitude of moon at the beginning of the maṇḍala (diurnal circle) in which CY occurs $= 6\frac{6978}{7021}$ muhūrtas of arc as balance of Citrā (α Virginis)

$$= 602 \frac{184646}{473825} \text{ muhūrtas of arc}$$

from the beginning of Abhijit (α Lyrae) (see table 3.3-1)

Let n be number of complete lunar maṇḍalas (diurnal circles) and x be the number of complete sidereal revolutions of moon since the beginning of the five-year cycle, before the CY occurs. Therefore, we have

$$nv_m = 819 \frac{27}{67} \cdot x + 602 \frac{184646}{473824}$$

$$\text{or } n \cdot \frac{54900}{1768} = \frac{54900}{67} x + 602 \frac{184646}{473824}$$

$$(\because v_m = \frac{54900}{1768} \text{ muhūrtas}$$

of arc/lunar maṇḍala (diurnal circle)

$$\text{or} \quad n = \frac{1768\,x + 1299.757}{67} \text{..................} (8.3\text{-}5)$$

By rounding off to integral numbers, eq. No. (8.3-5) may be written as

$$n = \frac{1786\,x + 1300}{67} \text{..................} (8.3\text{-}6)$$

Using Kuṭṭaka (pulveriser) and Valli method, i.e. theory of indeterminate equations of first degree, we find on solving eq. No. (8.3-5) that the least integral solution is given as

$$x = 17$$

$$n = 468$$

This means that the CY occurred in 469th lunar maṇḍala (diurnal circle) or more exactly, at the epoch when 468 $\frac{9}{40}$ lunar maṇḍalas were traversed since the beginning of the five-year cycle.

Now, $\because$ 1768 lunar maṇḍalas (diurnal circles) or lunar sāvaṇa days in time measure = 1860 lunar days

$$\therefore\ 468\frac{9}{40} \text{ lunar maṇḍalas (diurnal circles)}$$

$$= 492\frac{2085}{3536} \text{ lunar days}$$

$$= 16 \text{ lunar months and}$$

$$1\frac{2085}{3536} \text{ lunar days} \quad \ldots(8.3\text{-}7)$$

Thus referring to Jaina five-year fixed calender (see table No. 6 9-1), we find that thirteenth lunar day or the dark half of seventeenth lunar month (Mārgaśīrṣa month of the second lunar samvatsara or year) was in current when the CY was observed. As moon rises very late at night on thirteenth lunar day of the dark half of any lunar month, so the CY would occur only a little before sunrise.

(iv) At the beginning of the five-year-cycle, moon just starts its north-ward journey and covers 134 lunar ayanas during the period,[15] i.e. a five-year cycle or

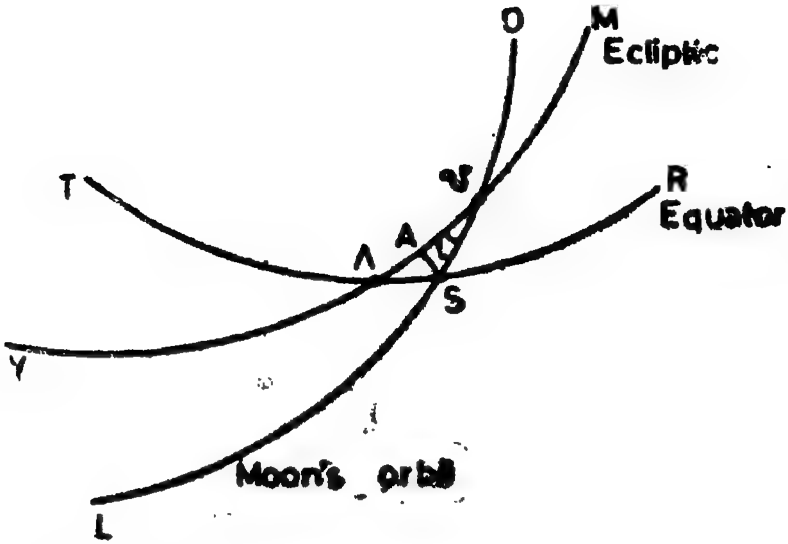
1768 lunar maṇḍalas = 134 lunar ayanas (halves of lunar sidereal revolutions)

$$\therefore\ 468\frac{9}{40} \text{ lunar maṇḍalas} = 35\frac{17243}{35360} \text{ lunar ayanas}$$

$$\text{Now } \frac{17243}{35360} = \frac{1}{2+}\ \frac{1}{19+}\ \frac{637}{874}$$

Evidently, $\frac{17243}{35360}$ is slightly less than $\frac{1}{2}$.

Therefore moon has covered a little less than half of the thirty-sixth lunar ayana on its south-ward journey. So moon lies just



Λ=Autumnal equinox
☋=The moon's descending node
i =Inclination of the lunar orbit to ecliptic

Fig No. 83—1. Chart showing the probability of occurrence of Chatratichatra yoga i.e. lunar occultation with Citrā (α Virginis).

north of the equator. At the same time moon occults Citrā (Spica) whose identifying star (α Virginis) has a celestial latitude[18]— 2° 03′ 10″

The exact position of moon may be located as just north to the equator and just south to the ecliptic. Therefore, to narrow down the region for the position of moon, let Citrā (α Virginis) lie just on the equtor (see fig. No. 8.3-1).

TR = Celestial equator

YM = Ecliptic

LO = The lunar path

$☋$ = The moon's descending node (ketu)

A = Autumnal equinox,

i = Inclination of the lunar orbit,

$\angle A \wedge S$ = Obliquity of ecliptic

$\therefore$ Latitude of Citrā (α Virginis), $AS = 2°$ approx.

In the right angled spherical triangle SA ☋, using Napier's rules for circular parts,[19] we have

$$\sin A☋ = \tan AS \cot i$$

$$= \tan 2° \cot 6° 38'24''$$

(Parallax corrected maximum latitude of moon, $i = 6° 38' 24''$)[20]

Using logarithmic tables,[21] it may easily be seen that

$$A☋ = 17°.5 \quad \text{.........................(8.3-1)}$$

Similarly, in right angled spherical triangle SA $\wedge$, we have

$$\sin A \wedge = \tan AS \cot A \wedge S$$

$$= \tan 2° \cot 23°.5$$

$$(\because A \wedge S = 23°.5) \quad \text{......................(see 2.3)}$$

And, $\sin AS = \sin \wedge S \sin A \wedge S$

or $\sin \wedge S = \sin 2° \operatorname{cosec} 23°.5$

$$\therefore A \wedge = 4°.6 \quad \text{......................(8.3-9)}$$

$$\text{and } \wedge S = 5° \quad \text{......................(8.3-10)}$$

Thus the moon passes through AS when

$$A☋ \approx \text{from zero to } 17°.5$$

But if ☋ coincides with $\wedge$, moon would not occult the star as $\wedge S = 5°$

As the CY lasts for only a small interval of time, the optimum maximum latitude of the star is AS so that moon could cause occultation under the given circumstances as discussed above. So ☋ should lie in the neighbourhood of A.

The phenomenon of CY under given conditions is little disturbed even if ♉ lies in the very neighbourhood of A. It appears that such an event of periodic coincidence of A and ♉ at the time of occurrence of CY points out that Citrā might have been considered as represented by a significant star (α Virginis) and the importance given to it due to the formation of CY might have contributed to the development, albeit inadequately, to an empirical origination of the concept of the present day Citrā ayanāmsa, i.e. measuring the precession of equinoxes with respect to Citrā[22] (α Virginis) whose longitude is taken as 180° from the first point of sidereal Meṣa (Aries sign).

(v) Again, we see that apparent angular distance of $\frac{9}{40}$ lunar maṇḍala $= 81^\circ$........................ (see eq. No. 8.3-2)

As CY could be observed only before surise, so angular distance between moon and the next sun must be not less than 84°. But corresponding to about 12¾th lunar day of lunar dark half (Mārgśīrṣa), angular distance between moon and sun cannot be greater than 30°. However, the difference of time interval between moonrise and sunrise is a complicated function of declinations of moon and sun, and latitude of observer.[17] The possible value of latitude of observer can be computed from the condition that the angular distance between moon and sun $\approx$ from 30° to 84°.

Let

ϕ = latitude of observer

δ_s = declination of sun

δ_m = declination of moon

H_s = Hour angle of rising sun

H_m = Hour angle of rising moon

Thus, with usual notion, we have

$$\cos H_s = -\tan\phi \tan\delta_s$$

$$\text{and } \cos H_m = -\tan\phi \tan\delta_m$$

$$\therefore\ H_m - H_s = \cos^{-1}(-\tan\phi\tan\delta_m) - \cos^{-1}(\tan\phi\tan\delta_s) \quad \text{........................(8.3-11)}$$

Now taking $H_m - H_s = 6\frac{3489}{3536}$ muhūrtas = 84° approx.

$\delta_s = -19°$ (approximately arbitrarily chosen for the months of Mārgaśīrṣa or November

$\delta_m = 0°$

∴ Eq. No. (8.3-11) is written as

Either $84° = 90° - \cos^{-1}(\tan\phi \tan 19°)$

or $30° = 90° - \cos^{-1}(\tan\phi \tan 19°)$

∴ Either $\phi = \tan^{-1} 2.88828 = 70°.9$ approx.

or $\phi = \tan^{-1} 1.45209 = 55°.4$ approx.

It may, however, be remarked here that the above calculations have been based on an incorrect dimension of the year which is slightly more than the true value. This is why angular d stance (84°) between moon and sun (see eq. No. 8.3-) is not consistent with lunar day of occurrence of CY. Ergo, Obviously, the above derivation of the latitude of observer cannot be depended upon.

(vi) Under the conditions of formation of CY as discussed above, it may easily be seen that the declination of moon is always greater than that of Citrā (α Virginis). We know that the declination of sun in the month of Mārgaśīrṣa (the month of fifth lunar mansion antelope's head or λ orionis of the present time is always less than that of Citrā (α Virginis)[28]. Therefore under these conditions, for an observer in the northern hemisphere the zenith distance of moon is lesser than that of Citrā (α Virginis) and that of sun is greater than that of Citrā (α Virginis). Probably such a notion is depicted in the relative positions that upper the moon, the star in between and lower the sun is situated at the time of formation of CY.

It may again be noted that only the CY is defined. Regarding the rest of the nine yogas (weal and woe conjunctions), nothing

more than their nomenclature has been found in any Jaina canonical text so far.

8.4 *DIURNAL MOTION OF ASTRAL BODIES*

In this section, the longitudinal motion of Jyotiṣikas (astral bodies) as implied in the Jaina canon will be dealt with. In this context, as regards the motion of moon and sun, SP. 15.2-3 states : (Quotation No. 8.4-1) i.e. "How many parts does moon cover in a muhūrta ?

> Moon moves (in a muhūrta) upon 1768 parts of the maṇḍala (diurnal circle) occupied by moon at that time, whereas the (lunar) maṇḍala (diurnal circle) is divided into 109800 parts.
> How many parts does sun cover in a muhūrta ?
>
> Sun covers 1830 parts of the (solar) maṇḍala (diurnal circle) occupied by sun at that time, whereas the (solar) maṇḍala (diurnal circle) is divided in 1 9800 parts.

It may be recalled that Jainas believed in the theory of two suns and two moons etc. So two moons and two suns would cover 109800 parts of their maṇḍalas (diurnal circles) respectively : either moon and either sun cover only 54900 parts of their respective maṇḍalas (diurnal circles). Besides, a lunar (solar) maṇḍala is traversed in a lunar sāvanā day i.e. moonrise to moonrise (solar sāvaṇa day i.e sunrise to sunrise .

Velocity of moon, v_m = 54900 parts/lunar sāvaṇa day (moonrise to moonrise)

But ∵ 1768 lunar sāvaṇa days = 1830 days

$\therefore\ v_m = 54900 \times \frac{1768}{1830}$ parts/day (day and night i.e. 30 muhūrtas)

= 1768 parts/muhūrta.

Similarly, velocity of sun, v_s = 54900 parts/solar sāvaṇa day (sunrise to sunrise)

= 1830 parts/muhūrta.

Further the lunar and the solar velocities have been compared. In this context, SP. 15.5 states : (Quotation No. 8.4-2)

i.e. "When moon completes its motion, and sun completes its motion, what is the specific character between the two motions ?

(The answers is) specific character of sixth-two parts (meaning that the sun moves upon sixty-two parts more than the parts moved upon by moon)."

Apparently it looks strange that sun moves faster than moon. But here the relative velocity of sun and moon has been viewed through the notion that they have a westward motion in their diurnal circles and the earth remains stationary. To illustrate this point, suppose on any day, sun and moon are simultaneously situated at the eastern horizon ; next day sun is at the horizon bnt moon has still to cover sixty two parts before it comes above the horizon. With this exposition it seems plausible that sun moves faster than moon.

Evidently $v_s - v_m = 1830 - 1768$

$$= 62 \text{ parts/muhūrta.}$$

$$= 62 \times 30 \text{ parts/day (day and night).}$$

$$\therefore \text{ Lunar synodic period} = \frac{54900}{62 \times 30} = 29.5161 \text{ day}$$

It is comparable with the modern value (29.5301 days).[6]
Now on the other hand,

Total angular distance traversed by sun in one solar diurnal circle $= 54900$ C.P. + Eastward v_s among the stars.

$$= 54900 \text{ C.P.} + \frac{54900}{366} \text{ C.P.}$$

(∵ 1 solar sidereal circle = 366 days

$$\therefore v_s = \frac{54900}{366} \text{ C.P./solar sāvaṇa day).}$$

$$= 54900 \times \frac{367}{366} \text{ C.P} \quad \cdots\cdots\cdots\cdots (8.4\text{-}1)$$

Similarly total angular distance traversed by moon in one lunar diurnal circle = 54900 C.P. + Eastward v_m among the stars

$$= 54900 \text{ C.P.} + \frac{54900 \times 67}{1768} \text{ C.P.}$$

($\because$ 67 lunar sidereal revolutions = 1768 lunar sāvaṇa days

1 lunar sidereal revolution $= \frac{1768}{67}$ lunar sāvaṇa days

$$v_m = \frac{54900}{1768/67} \text{ C.P./lunar sāvaṇa day.)}$$

$$= 54900 \times \frac{1835}{1768} \text{ C.P.} \quad \cdots\cdots (8.3\text{-}2)$$

Besides, the apparent solar or lunar diurnal circle has been divided in 54900 parts for all practical purposes.

54900 parts of a solar maṇḍala = 1 solar diurnal circle

$$= 54900 \times \frac{367}{366} \text{ C.P.}$$

......................(see eq No. 8.3-1)

1830 parts of a solar maṇḍala = 1835 C.P.

i.e. sun moves 1835 C.P. per muhūrta

Similarly,

1768 parts of a lunar maṇḍala = 1835 C.P.

i.e. moon moves 1835 C.P. per muhūrta.

This indicates that the apparent westward angular velocities of sun and moon are equal. This notion is exhibited in the sameness of solar and lunar velocities in yojanas per muhūrta when they occupy either of their common extreme maṇḍalas e.g the innermost (or outermost) maṇḍalas (diurnal circle) (see. chapter 5).

Like sun and moon, any nakṣatra (asterim) has also its diurnal circle. In this context SP. 15.4 states : Quotation No. 8.4-3)

i.e. "How many parts does a nakṣatra (asterism) move in one muhūrta ?

A nakṣatra (asterism) moves 1835 parts of its maṇḍala (diurnal circle) occupied by it at that time, whereas the maṇḍala (diurnal circle) is divided into 109800 parts."

Like before, velocity of nakṣatra (asterism),

v_n = 54900 parts/nakṣatra sāvaṇa day (nakṣatra rise to nakṣatra rise)

(∵ 1835 nakṣatra sāvaṇa days = 1830 days

$\therefore v_n = 54930 \times \frac{1835}{1830}$ parts/day (day and night).

= 1835 parts/muhūrta (1 day = 30 muhūrtas)

The velocities of sun, moon, and nakṣatra (asterism) in other units of time are also stated in SP. 15.11-17 as : (Quotation No. 8.3-4)

i.e. (20). (1) How many maṇḍalas (diurnal circles) does moon move in a nakṣatra month (lunar sidereal revolution) ?

Moon moves $13 \frac{13}{67}$ maṇḍalas (in a nakṣatra month).

(2) Sun......$13 \frac{44}{67}$ maṇḍalas.

(3) Nakṣatra...... $13 \frac{93}{134}$ maṇḍalas.

(21) (1) How many maṇḍalas (diurnal ciccles) does moon move in a lunar month)

Moon moves $14\frac{1}{4} + \frac{1}{124}$ maṇḍalas (in a lunar month)

(2) Sun...... $14\frac{3}{4} + \frac{1}{124}$ maṇḍalas.

(3) Nakṣatra...... $14\frac{3}{4} + \frac{6}{124}$ maṇḍalas.

(22). (1) How many maṇḍalas (diurnal circles) does moon move in a ṛtu (season) month ?

Moon moves $14 \frac{30}{61}$ maṇḍalas (in a ṛtu month).

(2) Sun......... 15 maṇḍalas.

(3) Nakṣatra.........$15\frac{5}{122}$ maṇḍalas.

(23). (1) How many maṇḍalas (diurnal circles) does moon move in a solar month ?

Moon moves $14 \frac{11}{15}$ maṇḍalas (in a solar month)

(2) Sun...... $15 \frac{1}{4}$ maṇḍalas.

(3) Nakṣatra......... $15 \frac{35}{120}$ maṇḍalas

(24). (1) How many maṇḍalas (diurnal circles) does moon move in an abhivardhana (lustfully increased month (1/12th of a lunar year with an intercalary month)

Moon moves $15\frac{83}{186}$ maṇḍalas (in an abhivardhana month).

(2) Sun...... $15\frac{245}{248}$ maṇḍalas.

(3) Nakṣatra ...... $16\frac{47}{1488}$ maṇḍalas.

(25). (1) How many maṇḍalas (diurnal circles) does the moon move in an ahorātra (day and night) ?

Moon moves...... $\frac{442}{915}$ maṇḍalas (in an ahorātra.)

(2) Sun...... $\frac{1}{2}$ maṇḍalas.

(3) Nakṣatra......... $\frac{367}{732}$ maṇḍalas.

(26). (1) How many maṇḍalas (diurnal circles) does moon move in a yuga (five year-cycle),

Moon moves 884 maṇḍalas (in a yoga)

(3) Sun......91 5 maṇḍalas.

(3) Nakṣatra...... 917$\frac{1}{2}$ maṇḍalas.

The velocities of these astral bodies i.e. moon, sun and nakṣatra (asterism), in other units of time i.e. nakṣatra month (lunar sidereal revolution), lunar month, ṛtu month (seasonal month), abhivardhana (lustfully increased) month, an ahorātra (day and night) and a yuga (five-year cycle) can easily be computed by keeping in view the following relation :

1 yuga = 67 nakṣatra months (lunar s.dereal revolutions)
(five-
year
cycle)

= 62 lunar months

= 61 ṛtu months (seasonal months)

= 60 solar months

= 57$\frac{3}{13}$ abhivardhana (lustfully increased) months

= 1830 ahorātras (days and nights)

= 54900 muhūrtas.

= 1830 solar maṇḍalas (diurnal circles) of 2 suns

= 1768 lunar maṇḍalas (diurnal circles) of 2 moons

= 1835 nakṣatra maṇḍalas (diurnal circles of asterisms) of 2 sets of nakṣatras (asterisms)

= 1768 lunar sāvaṇa days (moonrise to moonrise periods).

= 1835 nakṣatra sāvaṇa days (asterism rise to asterism rise periods).

For example,

In a yuga (five-year cycle), 2 suns move = 1830 maṇḍalas (diurnal circles)

Either sun moves = 915 maṇḍalas (diurnal circles)
Velocity of sun,

$$v_s = 915 \text{ maṇḍalas/yuga}$$

$$= \frac{915}{67} = 13\frac{44}{67} \text{ maṇḍalas/nakṣatra month}$$

$$= \frac{915}{62} = 14\frac{3}{4} + \frac{1}{124} \text{ maṇḍalas/lunar month}$$

$$= \frac{915}{60} = 15\frac{1}{4} \text{ maṇḍalas/solar month}$$

$$= \frac{915}{61} = 15 \text{ mandalas/ṛtu month}$$

$$= 915 \div 57\frac{3}{13} = 15\frac{245}{248} \text{ maṇḍalas/abhivarbhana month}$$

$$= \frac{915}{1830} = \frac{1}{2} \text{ maṇḍala/ahorātra}$$

A similar treatment holds good in case of the motion of moon and nakṣatras (asterisms).

8.5 *CLASSIFICATION OF JYOTIṢIKAS (ASTRAL BODIES) IN JAINA COSMOLGGY*

This section renders a simple exposition of the notion of set theoretic approach in the classification of Jyotiṣikas (astral bodies) in Jaina cosmology. The role of set theory therein is due to the

formation of various sets of Jyotiṣikas (astral bodics) in relation to their peculiar fundaments of size, shape, life-time (longevity), rays, Kṣetras i e spheres of action (tame i.e. darkness. and ātapa i.e. light or warmth), positions in several galactic lands and notion etc.

The set theoretic approach, as according to L.C. Jain,[27] had been developed in Jaina School of Mathematics for exposing a compendimum of all knowledge including the mathematical theory of karma (action) bonds and their annihilation. The mathematical and symbolic manipulation of all such events through a set theory is found in Artha Samdṛṣti Adhikāra being two independent chapters of Ṭoḍarmala's (before Circa A.D. 1761) commentaries of Nemicandrācārya's works like Gommatasāra Jīvakāṇḍa, Gommaṭasāra karmakāṇḍa, Labdhisāra and Kṣapaṇāsāra. Nemicandrācārya (circa tenth century A.D. prepared these condensed works from the earlier Prakrit texts like Ṣaṭkhaṇḍāgama which was composed probably during the first two centuries of the Christian era. Georg Cantor (1845-1918 A.D.) is however, credited with the original creation of the modern set theory.[28] The fundamental word basic to Indian mathematics is rāśi which, despite in several other contexts, is synonymical with samūha, ogha, puñja and synonyms for ogha are vṛnda, sampāta, samudaya, piṇḍa, awaśeṣa abhinna as well as sāmānya.[17] According to TSS. 747 rāśi forms one of the ten topics of discussion.[29] Here an attempt has been made to expose the set theoretic approach in the classification of Jyotiṣikas (astral bodies) in Jaina cosmology.

There are five classes of Jyotiṣikas (astral bodies). TSS. 401 states as : (Quotation No. 8.5-1)

> "There are five kinds of Jyotiṣikas (astral bodies), viz moon, sun, grahas (planets), nakṣatras (asterisms) and tārās (stars)."

Other explicit references are also found as :

1. PS. pada 1
2. BS. 5.9.17
3. TDS. 4.13

It is evident that moon and sun form different classes each of a single element only. Moon, as we know, is chiefly characterised with its phenomenon of periodic waxing and waning and sun with its regularity of diurnal motion. The significance of this classification lies in the fact that there exist two name-variant Jaina canonical works i.e. Sūrya Prajñapti and Candra Prajñapti which are otherwise all identical in contents dealing with the celestial phenomena, more or less, common with sun and moon. Likewise the set of nakṣatras (asterisms) consists of lunar stations among the stars and it is distinguished from the set of tārās (stars). Every nakṣatra (asterism) has one star at least or a more number of stars. Out of twenty-eight nakṣatras (asterisms), those having the same number of stars have been put together and form a subset of the set of nakṣatras (asterisms). For example, TSS.227 states that Abhijit (α Lyrae), Śravaṇa (α Aquilae), Aśvini (β Arietis). Bharaṇī (forty-one arietis), Mṛgaśirṣa (λ Orionis) and Puṣya (δ Cancri) nakṣatras (asterisms) have three stars each, etc. etc. Such subsets of the set of nakṣatras (asterisms) are ten in number.[30] (see 6.1).

A notion of subset of a set is also implied in the relation between mahāgrahas (great planets) and tārakagrahas (star-planets) In this context, SP. 20.18 states as :

(Quotation No. 8.5 2)

There are eighty-eight mahāgrahas (great planets), viz.

(1) Aṅgāraka
(2) Vikāloka
3. Lohityaka
4. Śanaiścāra (saturn)
5. Ādhunika
6. Prādhunika
7. Kaṇa
8. Kaṇaka
9. Kaṇakaṇaka
10. Kaṇavitānaka
11. Kaṇasantānaka
12. Soma
13. Sahita
14. Āśvāsana
15. Kāryopaga
16. Karbataka
17. Ajakaraka
18. Dundubhaka
19. Śaṅkha
20. Sankhanābha
21. Śaṅkhavarāḥbha
22. Kansa
23. Kansanābha
24. Kansavarṇābha
25. Nīla
26. Nīlāvabhāsa

27. Rūppi
28. Rūpyavabhāsa
29. Bhasma
30. Bhasmarāśi
31. Tila
32. Tilapuṣpavarṇaka
33. Daka
34. Dakavarṇa
35. Kāya
36. Bandhya
37. Indrāgni
38. Dhūmaketu
39. Hari
40. Piṅgala
41. Budha (Mercury)
42. Śukra (Venus)
43. Bṛhaspati (Jupiter)
44. Rāhu (Dragon's head)
45. Aṅgasti
46. Māṇavaka
47. Kāmasparsa
48. Dhura
49. Pramukha
50. Vikaṭa
51. Visandhikalpa
52. Prakalpa
53. Jatāla
54. Aruṇa
55. Agni
56. Kāla
57. Mahākāla
58. Svasitaka
59. Sauvasitaka
60. Varddhamanaka
61. Pralamba
62. Nityāloka
63. Nityodyota
64. Svayamprabha
65. Avabhāsa
66. Śreyaskara
67. Ahamaṅkara
68. Ābhaṅkara
69. Prabhaṅkara
70. Arajā
71. Virāja
72. Aśoka
73. Vītaśoka
74. Vivartta
75. Vivastra
76. Vivaste
77. Viśāla
78. Śāla
79. Buvrata
80. Anivṛtti
81. Ekjaṭī
82. Dvijaṭī
83. Kara
84. Karika
85. Rāja
86. Argala
87. Puṣpaketu
88. Bhāvaketu."

JP. 10.16 and TSS. 90 also give the same list. JPS.12.87 also refers to eighty-eight mahāgrahas (great planets). But in Candra Prajñapti,[18] Aśoka (72) and Vītaśoka (73) from only one mahāgraha Asogevīyasogeya whereas Bhāvaketu (88) is split up into two mahāgrahas, viz. Bhava and Keū.

Besides in TSS, two more mahāgrahas (great planets) – Pūsamnānaka and Aṅkuśama—are placed inbetween Vaddhamāgaṇa

(60) and Palamba (61) ; besides Rākamī (27) and Rūkmabhāsa (28) are placed before Nīla (25) and Nīlābhasa (26). According to JP.7 15-22, we however come across with the list of eighty-eight mahāgrahas (great planets) but with some slightly different names.

On the other hand, a different set of tāraka-grahas (star planets) is also stated in TSS. 481 as : Quotation No. 8.5-3)

> "There are six tāraka-grahas (star planets,) viz Śukra (venus), Buddha (mercury), Bṛhaspati (jupiter,) Aṅgāraka (mars), Saṇccara (saturn) and Ketu (dragon's tail ?)."

According to PVS.3, there are nine Jyotiṣika devas (astral divine bodies) viz. Bṛhaspati (jupiter), Candra (moon), Sūrya (sun), Śukra (venus), Saṇccara (saturn), Rāhu (dragon's head), Dhumaketu (Dragon's tail ?), Buddha (mercury and Maṅgala (mars). The same list of nine tārakagrahas (star planets) is also stated in BS. 117 and they are mentioned as devas (divine bodies) who are said to obey good 'Soma'. As we find in Gītā (xvi), the holy book of Hindus, that the terms 'devas' and 'asuras' have been used for races in which daivī (divine) or asurī develish traits preponderate;[81] It appears that Jyotiṣika devas (astral divine bodies) probably formed the set of celstial bodies in which daivī (divine) traits preponderate. One of the daivī (divine) traits might be that Jyotiṣika devas (astral divine bodies) were understood to regulate the astrological prognostications, for two shadowy planets Rāhu (moon's ascending node) and Ketu (moon's descending node) have also been included in the list of devas (divine bodies).

The set of tāraka-grahas (star planets) seems to imply also that every member of it has the tāraka (star like) appearance Mathematically, let the sets of traka-grahas (star planets) and mahāgrahas (great planets) be denoted by T and M respectively. Using popular notations, we have

$T = \{x : x \text{ is a tārakagraha (star planet)}\}$

and $M = \{y : y \text{ is a mahāgraha (great planet)}\}$

Now we find that Ketu (moon's descending node) $\in T$ (see Quot. No. 8 5-3) and Ketu $\notin M$ (see Quot. No. 8,5-2) ; but keeping in

view what Alberūnī mentions that Hindus seldom speak of dragon's tail (Ketu), they only use dragon's head (Rāhu),[32] it may be envisaged that Rāhu $\in$ M (see quot. No. 8.5-2) denotes both Rāhu (dragon's head) and Ketu (dragon's tail). With this supposition, we find that T can be one-one mapped into M, i.e.

for any $x \in T$, $\exists\, y \in M$

but $x = y$ (by inspection).

$\therefore T \subset M$

$\therefore T = T \cap M$

or $T' = (T \cap M')$ where $T' = M \sim T$ i.e. $T' \cup T = M$

$\therefore T' = \{z : z \notin T, \text{ or } z \notin T \cap M\}$

Thus T' denotes the set of mahāgrahas (great-planets) and no tāraka-graha (star planet) is included in it

Now we have to search for what the concept of a mahāgraha (great planet) stands for. Suppose that

$T' = \{ z : z \text{ is a commet}\}$

Incidently, an American astronomer (name ?) has defined a 'comet' as 'something' that is just different enough from nothing to be something.[33] Comets exhibit great diversity in size and brilliance. Sometimes it happens that a comet is so bright as to be visible even before sun has not yet sunk below the horizon but the majority are invisible to the nakedeye. Down to tne invention of the telescope, the discovery of comets had been left to chance and it was not until towards the close of the eighteenth century when two frenchmen astronomers started their systematic efforts to search for comets [35] In this context, Alberūnī mentions that in general all comets which appear on heaven are called Ketu[36] (moon's descending node). But even if we fiind that T' includes three Ketus, viz. Dhūmaketu, Puṣpaketu and Bhāvaketu, Alberūnī's view cannot be generally accepted. Alberūnī has also given a list of comets,[32] which includes only two members of T' viz. Kaṇaka (8) and Bhāvaketu (88). Varāhamihira (A.D. 505—587) in his Bṛhat Sanhitā (iii.7-12) mentions that the number of comets accor-

ding to some is 101 and according to others 1000. According to the sage, Nārada, they are only one which appears in a multitude of different forms, always divesting itself of one form and arraying itself in another. The number 101, of course; suggests as if it had been raised from eighty eight, the number of mahāgrahas (great planets).

In the light of foregoing discussion, it seems plausible that any starlike body moving among the stars was probably thought of a mahāgraha (great planet) and the one with the known periodic motion was also called a tāraka graha (star planet). The lunar nodes which are actually nothing more than mere shadows, were called by the only name 'prava rāhu' (see 8.1). So 'prava rāhu' denoting rāhu (moon's ascending node) and ketu (moon's descending node) was therefore probably included in the set of tārakagrahas (star planets). So rāhu $\in$ M probably denotes 'parva rāhu,' the word 'parva' might have been dropped after its repeated use ; however ketu $\in$ T probably denotes moon's descending node and rāhu $\in$ T (according to PVS 3) denotes the other node. Besides, according to TSS, rāhu $\notin$ T ; but according to PVS.3, rāhu $\in$ T. This suggests that periodic motion of rāhu might have not been known before PVS was compiled. Absence of an accurate knowledge of true motion of rāhu is also exhibited in the theory of Jaina cycles of eclipses (see 8.1).

But it would have been better understandable if (parva) rāhu (denoting both rāhu i.e moon's ascending node, and ketu i.e. moon's descending node) would have been $\in$ T. and instead ketu would have been $\in$ T$'$; then ketu could have conveniently been taken as a class of comets in partial agreement with what Alberūnī says that in general, all comets which appear on heaven are also called ketu. Probably rāhu and ketu have later interchanged their positions as reported in the given data as discussed above.

Regarding the number of tārās (stars), JP.7.1 states : Quotation No. 8.5-4)

"There are 133950 tārās (stars)."

Regarding the longevity of Jyotiṣikas (astral bodies), JPS (cf JPS. 12.95-96) mentions that the utkṛṣṭa (excellent) life time of

moon is one lac and one palya years, of sun is one thousand and one palya years, of venus is one hundred and one palya years, of jupiter is one palya years and of the rest of grahas (planets) is half the palya years each. Each of the tārās (stars) has its jaghanya (low) life time of 1/8 palya years and utkṛṣṭa (excellent) life time of 1/4 palya years. Incidently it may be remarked that Kapla Sūtra[34] records that a mahāgraha (great planet) Bhasma (see quot. No. 8 5.2) remained in Uttarāphālgunī (β Leonis) for 2000 years. However, palya denotes an asaṅkhyāta (non-measurable but not infinite) measure of time.[36] Though the rationale of determining the longevity of Jyotiṣikas (astral bodies) is still beyond apprehension, yet it exhibits a notion of classification of Jyotiṣikas (astral bodies) according to a certain pattern. A similar notion of classification of Jyotiṣikas (astral bodies) exhibited in the pattern of their distribution over several galactic lands as reported in Trilokasāra of Nemichandra (tenth century A D). Likewise the symmetry of placing all the heavenly bodies in Madhyaloka can also be taken into consideration.

All the sets of Jyotiṣikas (astral bodies) are asaṅkhyāta (non-countable).

* * * * *

APPENDIX I

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APPENDIX II

LIST OF TECHNICAL TERMS

Abhivardhana	=Lustfully increased	अभिवर्धन
Āgama	=A system of philosophy	आगम
Ahorātra	=Day and night	अहोरात्र
Airāvata	=Chief elephant (God Indra's elephant)	ऐरावत
Aja	=He-goat	अज
Amāvasyā	=New-moon day	अमावस्या
Aṅga	=Limb	अंग
Aṅgula	=Finger width	अंगुल
Anuyoga	=One of the four divisions of Jain canonical literature	अनुयोग
Apasarpiṇī	=Retreat (used for descending half of time-wheel)	अपसर्पिणी
Asaṅkheya	=Innumerable	असंख्येय
Asura	=Demon	असुर
Āvalikā	=A small measure of time (Jaina units)	आवलिका
Ayana	=Sun's (or Moon's) northern or southern journey	अयन
Bṛhaspati	=Jupiter	बृहस्पति
Budha	=Mercury	बुध
Candra	=Moon	चन्द्र
Candrāyana	=Moon's northern or southern journey	चन्द्रायन
Caraṇānuyoga	=A class of Jaina canonical literature	चरणानुयोग
Chatra	=Umbrella	छत्र

Chatrātichatra yoga	=Overlapping like an umbrella' denoting lunar occultation with Citrā (α Virginis)	छत्रातिछत्र योग
Cheda Sūtras	=Cut ropes	छेद सूत्र
Citrāpakṣīya	=Pertaining to the Citrāpakṣīya School of astronomy according to which first point of zodiac lies at 1:0° from Citrā (α Virginis)	चित्रापक्षीय
Cūlikā	=Apex or summit	चूलिका
Dahana	=Fire	दहन
Dakṣiṇāyana	=Southern course (of sun or moon)	दक्षिणायन
Daṇḍa	=Staff (stick)	दण्ड
Deva	=Angel (divine being)	देव
Dharmakathānuyoga	=A class of Jaina canonical literature	धर्मकथानुयोग
Dhūmaketu	=A comet	धूमकेतु
Dhruva Rāhu	=The mythological Dragon's head which is supposed to devour the waning moon	ध्रुव राहु
Digambra	=A sect of Jainas who wear no clothes	दिगम्बर
Dṛk	=Observational	दृक्
Gaja	=Elephant	गज
Gaṇitānuyoga	=A class of Jaina canonical literature dealing with geography and astronomy	गणितानुयोग
Ghaṭikā	=A Jaina measure of time (=24 minutes)	घटिका
Graha	=Planet	ग्रह
Grīṣma	=Summer	ग्रीष्म
Gau	=Cow	गौ

Hasta	=Hand-length	हस्त
Haya	=Horse	हय
Hemanta	=Winter	हेमन्त
Illahi gaz (Illāhi gaza)	=Dvine yard	इल्लाही गज
Jaghanya	=Low (as implied in Jaina systems of units)	जघन्य
Jambūdvīpa	=Isle of Jambū tree	जम्बूद्वीप
Jaradgava	=Old bull	जरद्गव
Jyotiṣa	=Astronomy	ज्योतिष
Jyotiṣika	=Astral body	ज्योतिषिक
Karaṇa	=Half-tithi (half lunar day)	करण
Ketu	=The mythological Dragon's *tail*	केतु
Kosa (Krośa)	=A measure of length	कोस (क्रोश)
Kṛsṇâdi paddhati	=Lunar calendar with months ending with amâvasyā (new-moon day)	कृष्णादि पद्धति
Kṣetra	=Tama (darkness) and âtapa (light) fields	क्षेत्र
Kula	=Category	कुल
Kulopakula	=Sub-sub-category	कुलोपकुल
Kumbha	=Aquarius	कुम्भ
Kuṭṭaka and Vallī method	=Pulverizer and theory of indeterminate equation	कुट्टक एवं वल्ली विधि
Laksaṇa	=Symptom	लक्षण
Laukika	=Prevalent	लौकिक
Lavaṇasamudra	=Salt ocean	लवणसमुद्र
Liksa	=Mini louse	लिक्षा
Lokottara	=Non-prevalent	लोकोत्तर
Mañca	=An elevated shed in a field (in the text, one of the ten types of occultation)	मंच

Mañcātimañca	=Higher elevated shed in a field (in the text, one of the ten types of occulation)	मंचातिमंच
Maṇḍala	=Diurnal circle	मण्डल
Maṇḍukapluta	=Skipping over any portion like a frogleap (in the text, one of the ten types of occultation)	मंण्डुकप्लुत
Maṅgala	=Mars	मंगल
Māsa	=Month	मास
i) Caitra	=First month of current Hindu calendar	चैत्र
ii) Vaiśākha	=Second month	वैशाख
iii) Jyeṣṭha	=Third month	ज्येष्ठ
iv) Āṣāḍha	=Fourth month	आषाढ़
v) Śrāvaṇa	=Fifth month	श्रावण
vi) Prauṣṭhapada	=Sixth month	प्रोष्ठपद
vii) Āśvina	=Seventh month	आश्विन
viii) Kārttika	=Eighth month	कार्तिक
ix) Mṛgaśirṣaka	=Ninth month	मृगशीर्ष
x) Pauṣa	=Tenth month	पौष
xi) Māgha	=Eleventh month	माघ
xii) Phālguṇa	=Twelfth month	फाल्गुन
Mṛga	=Deer	मृग
Meru	=Name of a fabulous mountain placed at the centre of Jambūdvīpa (isle of Jambū tree)	मेरु
Meṣa	=Aries	मेष
Muhūrta	=A measure of time (=48 minutes)	मुहूर्त
Mūla Sūtras	=Original ropes (original texts)	मूल सूत्र

Nāga	=Snake	नाग
Nakṣatra	=Asterism	नक्षत्र
Nakṣatra month	=Lunar sidereal revolution	नक्षत्र मास
Nigamas	=Jaina Upaniṣads (certain mystical writings the aim of which is the ascertainment of the secret sense of Jaina canonical works)	निगम
Nirvāṇa	=Salvation or liberation from corporeal existence	निर्वाण
Pāda	=Foot-length	पाद
Pakṣa	=Half lunar month	पक्ष
Palya	=A big measure of time	पल्य
Paramāṇu	=Atom	परमाणु
Paramāṇukāla	=An atom of time	परमाणुकाल
Parva	=Half lunar month	पर्व
Parva Rāhu	=The mythological dragon's head which is supposed to devour the sun or moon during an eclipse	पर्व राहु
Paurasī	=Partaining to puruṣa (man-lengths)	पौरसी (पौरुषी)
Paurasī shadow	=Used for monthly increment in the gnomonic noon-shadow-length measured in units of puruṣas (man-lengths)	पौरसी छाया
Pramāṇa	=Authentic	प्रमाण
Prāṇa	=Breath	प्राण
Prakīrṇakas	=Dispersed texts of Jaina canonical literature	प्रकीर्णक
Pre-Siddhāntic	=Prior to Siddhāntic (theoretical astronomical) period	पूर्व-सिद्धांतिक

Prīṇita	=Pleased	प्रीणित
Pūrṇimā	=Full-moon day	पूर्णिमा
Puruṣa	=The height of a man considered as a measure of length	पुरुष
Pūrvas	=Former scriptures	पूर्व
Rāhu	=Dragon's head	राहु
Rāśi	=Sign	राशि
Raivata-pakṣīya	=Pertaining to Raivata-pakṣīya School of astronomy according to which first point of zodiac lies at Revatī (ξ Piscium)	रैवतपक्षीय
Ṛtu	=Season	ऋतु
Rūpa-Kuṭṭana	=Auxiliary K-equation	रूप-कुट्टन
Samatala bhūmi	='Earth having plane surface' denoting circular area with centre at the projection of pole of ecliptic	समतल भूमि
Samaya	=Time (Used for smallest Jaina unit of time)	समय
Saṃvatsara	=Year	संवतसर
Sanhitā	=A collection	संहिता
Saniccara	=Saturn	सनिच्चर
Sankrānti	=Solar ingress into a sign	संक्रान्ति
Śaṅku	=Gnomon	शंकु
Saura day	=The time taken by sun to traverse 1/360th part of zodiacal circle	सौर दिन
Sāvana day	=Civil day (sunrise to sunrise)	सावन दिन
Siddhānta	=System	सिद्धान्त

Sīmāviṣkambha	=Used for diameter of a circle and also used for zodiacal stretches of of nakṣatras	सीमाविष्कम्भ
Sauvarṇika	=A weight measure	सौवर्णिक
Śruta-jñānī	=Learned person taught through verbal instruction	श्रुत-ज्ञानी
Śuklādi paddhati	=Lunar calendar with months ending with pūrṇimās (full-moon days)	शुक्लादि पद्धति
Śukra	=Venus	शुक्र
Sūrya	=Sun	सूर्य
Svetāmbra	=A sect of Jainas wearing white clothes	श्वेताम्बर
Syādvāda	=(Jaina) theory of relativity	स्याद्वाद
Tārā	=Star	तारा
Tāraka-graha	=Star planet	तारक-ग्रह
Tīrthaṅkara	=Ford-maker	तीर्थंकर
Tithi	=Lunar day	तिथि
Upakula	=Sub-category	उपकुल
Upāṅga	=Sub-limb	उपांग
Uraga	=Raptile	उरग
Utkṛṣṭa	=Excellent	उत्कृष्ट
Utsarpiṇī	=Ascent (used for ascending half of time-wheel)	उत्सर्पिणी
Uttarāyana	=Northern course (of sun or moon)	उत्तरायण
Vaidhṛti Yoga	=Combination of sun and moon with equal and opposite declinations in the same ayaṇa	वैधृति

Vaiśvānara	=An epithet of Fire	वैस्वानर
Varṣā	=Rainy season	वर्षा
Vedāṅga Jyotiṣa	=Vedic astronomy	वेदांग ज्योतिष
Veṇukānujāṭa	=Combination like a bamboo (in the text, one of the ten types of occultation)	वेणुकानुजात
Vitasti	=Span	वितस्ति
Vīthi	=Lane	वीथि
Vṛṣa	=Bullock	वृष
Vṛṣabhānujāta	=Combination like a bull (in the text, one of the ten types of occultation)	वृषभानुजात
Vyatīpāta Yoga	=Combination of sun and moon with equal declinations in opposite ayanas	व्यतीपात
Yava	=Barley corn	यव
Yojana	=A measure of length	योजन
Yuga	=Cycle (like 5-year cycle)	युग
Yugādha	=Half-yuga	युगाद्ध
Yūka	=Louse	यूक

INDEX